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PRESIDENT'S MESSAGE

D. G. Malcolm

Some Effects Caused by Changing Values in Organizational Thinking

Before proceeding with the text of this message, I should like to extend congratulations and sincere welcome to the officers and members of A.I.I.E.'s newest chapters—Miami, Baton Rouge, Baltimore and Sacramento. It is also time to start your plans to attend the National Convention and Conference in St. Louis and the Regional Conference in Washington. I hope to see you at both these fine meetings.

In the last issue of the Journal I discussed a tendency in some industrial engineering situations to become preoccupied with the "installation" and/or "maintenance" phases of the total job of industrial engineering. Too often this has resulted in neglection of the problem definition, evaluation and design aspects of the engineers' job, thereby reducing the job requirements to those satisfiable by a technician rather than a professional engineer.

The professional engineer is responsible first for defining the system in which the problem occurs and then for identifying and determining the effect of all the factors important in the solution. Some of our approaches in industrial engineering may tend to create the impression that we have adequately formulated the problems some years ago and that there is nothing left to do but work out the details of the specific solution.

Now it seems to me that some of the trends that have become apparent in management thinking in the past decade bring the need for *new* solutions and more complete problem (or system) definition forceably to our attention. Let me illustrate this point.

Not very many years ago most corporations were operated with monetary gain ("profit") as the primary, and often, only goal. Fortunately, some corporations were led by individuals who did not accept the "profit motive" as the basic motivation for their company's

(Continued on Page 20)

JOB DESIGN

By: Louis E. Davis, *Dept. of Engineering*, and Ralph R. Canter, *Dept. of Psychology*, *University of California, Berkeley*

Industry has long been concerned with the problem of obtaining effective work from the persons employed to carry out the work of its various jobs. This is as real now as it ever has been. Although increases in productivity are still being achieved, the rate of improvement has slowed. In addition, it is believed by many who study the industrial scene that improvements in productivity are not due to the effectiveness of individual workers. Industry's approach to increasing productivity historically has been through the development of new processes, mechanization, improved tools and machinery, wage incentive systems, improved working conditions, better industrial relations, more effective scheduling, and so on. Such improvements as have been achieved have largely been credited to more skillful management and to greater availability and better use of capital.

It is our purpose to point out that little attention has been devoted to the question: What constitutes an effectively designed job? Is it possible to improve the organization of the work and the dividing up of the work into jobs so that the individual performing in the job can improve his productive contribution? We wish to suggest that productivity may be improved through the avenue of more effective job design.[1]

With the exception of engineers — and they are not informing anyone to the contrary — the assumption is very widely held that once established, a job and its contents are unalterable and inviolate, that the alternatives available in specifying the design of a job are severely limited. Those who are concerned with industrial jobs in various contexts, such as personnel administrators, budget directors, vocational counselors, placement agencies, etc., are most prone to regard a job, as designed, as a basic unalterable unit. Even those intimately concerned with production appear to act in the firm belief that the job and its contents are fixed by specific requirements of a process or of the organization, and that the job design specified by the engineering staff or others directly associated with job design is the only one which can satisfy the requirements. While the job will continue to be a basic unit of industrial organization, evidence is now accumulating that it is profitable to examine carefully the design of jobs with a view toward developing an effective (productive) job insofar as the individual, the organization, and the process are concerned.

The Concept of Job Design

Just what is job design? In our terms it is the organization of a job to satisfy the technical-organizational requirements of the work to be accomplished and the human requirements of the person performing the work. Let us now define terms prior to further discussion of the concept of job design. The following illustration and definitions indicate the meaning of terms used in this paper.

To carry out the process of making a shaft the following work operations are required: (Note: certain work elements have been omitted)

PROCESS: Make shaft (per drawing and specifications)
- **OPERATION 1.** Cut stock to length on power saw
  - **ELEMENT A.** Pick up stock, place against stop
  - **ELEMENT B.** Clamp stock and advance saw
  - **ELEMENT C.** Engage power and cut off piece to measured length
  - **ELEMENT D.** Remove piece cut off and place in tote box
- **OPERATION 2.** Face one end on lathe
- **OPERATION 3.** Face second end on lathe
- **OPERATION 4.** Rough turn diameter
- **OPERATION 5.** Finish turn diameter

The combined series of steps is called a process. A process therefore can be defined as follows:

PROCESS—the complete systematic sequence of operations required to produce an item, part, or complete product

In the case of clerical work, the term Procedure is equivalent to the process and is considered as a specialized process consisting of the complete systematic sequence of steps required to process a document or form through the established organizational and procedural channels.

Each of the major steps in the above illustration is called an operation, which is defined as follows:

OPERATION—a discrete, self-contained portion of a process or procedure, usually involving several separate work elements, and undertaken to complete one functional phase in making a part or in carrying out a procedure. An operation is usually performed in a single location and generally is repetitive in nature.

In the illustration, the activities needed to carry out the first operation are given. These are called elements and are defined as follows:

ELEMENT—a small, homogeneous subdivision of an operation, readily identified and defined, which is composed of a combination of manual movements and machine, chemical, or other actions and events.

The terms process, operation, and element describe a manufacturing sequence in terms of the requirements of the product as modified by the available equipment and facilities. In addition, the assignment to individual workers of the work activity in the manufacturing sequence must be considered. The following two terms are used to describe the assignment of work to individuals.

TASK—a work activity assigned to a person, which may be as small as one element or as large as the entire operation.
JOB—the total of the tasks assigned to an individual, which may be as small as one task composed of one element of an operation or as large as all of the tasks composed of all the operations required to complete one or more processes.

Referring to the process illustrated above, a task may be as large as Operation 1 or as small as Element 1A. If an individual is assigned only one task, perhaps as small as Element 1A, then this task is also his job, since a job is the total of the tasks assigned.

Since we see jobs as being composed of assigned tasks, the process of job design is accomplished by carrying out the following three activities:

1. specifying the content of individual tasks
2. specifying the method of performing each task, including the machinery and tools used and any special techniques
3. combining individual tasks into specific jobs

The first and third activities determine the content of the job, while the second indicates how the job is to be performed. The process of designing job content, we refer to as job design, and that of designing job methods as methods design.

Job design is, or should be, a part of the manufacturing planning procedure. Some efforts toward job design must be made in any such planning procedure where the manufacturing process is not entirely an automatic one. But it appears that job design in many case is considered to be a minor—if not automatic—step in this planning phase. Methods design is a much better understood activity, and we shall not devote any discussion to it here.[2]

The Need for Principles of Job Design

We believe that there is an important need to determine the principles which can best guide job designers in answering questions such as the following:

[1] Walker, C. R. "Work Methods, Working Conditions and Morale," **Industrial Conflict**, Society for Psychological Study of Social Issues, to be published.

[2] Davis, L. E., "Work Methods Design and Work Simplification," **Progress in Food Research**, Vol. IV, ed. E. M. Mrak, G. F. Stewart, 1952, Academic Press, N.Y.

a. In regard to the manufacturing process, which are the work elements, operations, and processes?
b. Which element (or elements) or operation (or operations) should be formed into a task or tasks?
c. Which task or combination of tasks should be formed into jobs?

It is likely that there will be a dozen or more principles needed to provide the necessary guidance. We can not at this time state the principles; we can only suggest the probable form of such principles. Tentatively it appears that the following kinds of governing principles will be required, i.e., principles regarding:

a. optimal size of job
b. degree of homogeneity of tasks
c. optimal amount of task repetition
d. optimal level of skill required
e. degree of task importance and meaningfulness as seen by operator
f. optimal rate of energy expenditure by operator
g. optimal degree of freedom of movement and task performance to allow for individual differences among operators
h. optimal job content relations among various jobs and sequences of jobs as concerns such matters as the responsibility for the sequences of tasks performed as a job, where not specifically fixed by the process, the flow of information between jobs, etc.

Of course there are a number of other kinds of factors and principles which have specific influence upon the design of the job, but these appear to us to be relatively indirect in their effects upon job design. Some of these other factors are in the areas of employee selection, training, conditions of work, organizational factors such as type of supervision practiced, personnel policies such as promotion program, tooling and equipment programs, type of production control, quality control program, and so on. Actually the fact that there are a large number of other factors and principles impinging upon the job and the worker in the job, only more fully illuminates the fundamental and underlying significance of the nature and content of the job. Further, the fact that the variables affecting the job are so interrelated only emphasized the very great need to examine the designs of jobs very carefully through extensive research and controlled experimentation.

The Criterion Problem

Obviously criteria are required to measure the effectiveness of various possible job designs. Many aspects of the job and the worker could serve as criteria, such as job satisfaction, fatigue, monotony, social climate, etc. So far little success has been achieved with these as criteria. However, since the effects of job design are usually discussed in terms of productivity (as they should be), we shall be concerned only with giving a definition of productivity, and some related concepts, which can serve as an appropriate criterion.

Productivity may be defined as the rate of production given a specific task to perform. It is the units of product produced per unit of labor, or per man-hour for a specified task or job. For our purpose it may be best to think of productivity as direct productivity, which is performance per specified period of time, or the immediate rate of production per man-hour of labor. This is direct productivity and is the definition commonly referred to in the literature and in government reports on productivity.

It is important for us, however, to distinguish direct productivity from what we refer to as economic productivity. Economic productivity is direct productivity modified by the inclusion of appropriate "overhead" or hidden charges, that is long-term time, money, flexibility, cooperative, supervisory, and especially psychological stress costs of such factors as:

labor turnover
absenteeism
amount of learning time
lack of flexibility of work skills
product quality deficiencies associated with job performance
production bottlenecks relating to the various jobs
grievances and interpersonal conflicts about job and process requirements
lack of adaptability or flexibility of the organization
supervision and inspection demands
lack of coordination and cooperation
industrial engineering and other engineering service requirements
personnel department service requirements
other service requirements such as maintenance
other overhead cost factors

It is our contention that such various cost factors (where cost is an index) must be incorporated into the economic productivity criterion, and that this "total cost" criterion, albeit complex, would provide the best sort of standard against which to evaluate various job designs. The primary operational gauge of the success of any given design would be the amount of reduction in total cost obtained in comparison with other designs.

Some History

There is no available published material which concerns the problem of job design from the standpoint of maximizing economic productivity (minimizing total cost). However, considerable published material is available concerning some methods of job design for maximizing direct productivity (minimizing immediate costs, mainly direct labor costs). Such job design methods relating to direct productivity may be grouped into three types: (1) process-centered approach to job design, (2) worker-centered approach, and (3) combination of process-centered and worker-centered approaches. Later, we shall suggest a fourth, the job-centered approach.

Under the heading of process-centered approach, there are two main methods that have been and are reportedly in use today for the design of jobs: (1) the specilization of labor[3] as the basis for minimizing direct labor costs; and (2) the rational method,[4] wherein predetermined standards (or estimates) of production are set for various methods of performing a manufacturing process and the minimum immediate cost method is chosen. In these approaches, consideration is given almost exclusively to dividing and subdividing the manufacturing process in regard to technical factors such as tooling, equipment, available space, etc.; to work and material flow systems, such as conveyors, fork-lift trucks, etc.; and to the utilization of manpower, equipment, etc.

The worker-centered approach is recent in origin, having arisen largely in the last 10 to 15 years, and is represented by two main methods: (1) the group-planning method,[5] in which a team of workers participates in deciding on the contents of the various jobs performed by the members of the work group. This is a newer method used in some segments of industry, notably in maintenance activities where the nature of the work changes rapidly. (2) job enlargement,[6] the most recent attempt to develop a comprehensive method of job design having the stated goal of attempting to maximize economic productivity. In this method the job is designed in such a manner that the operator performs a longer sequence of operations, or a larger number of relatively diverse operations. Often he is responsible for testing the quality of his own work, for setting up and maintaining production equipment, and for controlling his own production rate. The worker-centered approach lays special emphasis upon giving meaning to the work situation by enabling the worker to participate in certain areas of decision-making, thereby enhancing ego satisfactions.

The next class of methods involves a combination of the process-centered and worker-centered approaches which includes: (1) tradition-determined methods, in which the design of the job has been fixed in terms of the past evolutionary history of the job. This usually means that specification of job design is not, or can not be, undertaken by the

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[3]Thuesen, H. G., Lohman, M. R., "Job Design," Parts I and II, **Oil and Gas Journal**, 1943, Vol. 41, No. 35, 36.

[4]Maynard, H. B., Stegemerten, G. F., Schwab, J. L., **Methods-Time Measurement**, 1948, McGraw-Hill, N.Y.

[5]Woodhead, E. A., "Job Break-down Under Group Study Plan," **Electrical World**, 1943, Vol. 120, No. 24.

[6]Walker, C. R., "The Problem of the Repetitive Job," **Harvard Business Review**, 1950, Vol. 28, No. 3.

designers of jobs. (2) job-rotation,[7] in which the operator is assigned a series of jobs to be performed in rotated order. This method may be used to counteract poor productivity consequences of the design of certain of the jobs. In this combination class, consideration is generally in the main given to process requirements, but with some specific thought to the tasks which the operator must perform.

From the fore-going, it is quite apparent that fundamental job designs have changed drastically throughout the development of the industrial system. The changes made and the methods used have been based mainly on immediate economic considerations. However, it is quite probable that social science research developments have had a pronounced effect. Research has been conducted on job satisfaction, monotony or boredom, personal and group relationships, social organization, communication, participation, etc. Such research has shown the critical importance of the behavior of the worker as a factor in the modern technological system. It is likely that the concept of the worker-centered approach was formulated as a consequence of some of the research results.

However, it is also likely that the current philosophy of job design is still built upon the concept of minimizing immediate financial costs, with little operational consideration given to the concept of minimizing total cost.

Limitations of the Process-Centered and Worker-Centered Approaches to Job Design

There are a number of practical difficulties in the use of the process-centered and worker-centered approaches to job design which need to be pointed out. As previously indicated, the process-centered approach usually takes the requirements of the technical process as all-important in the assignment of tasks to workers. If, as so often happens, the process is changed in some manner, it becomes necessary to determine anew how the process will be divided into work elements and work operations, and how these will be formed into tasks and jobs. One major difficulty is found in the initial lack of flexibility of the design of the jobs. Any changes in design quite often results in resistance to change, voluntary restrictions in output, etc. on the part of the workers. That is, the jobs have been so shaped by the technical process requirements that any extensive process change causes almost every job to be altered radically with resulting worker insecurity reactions. Furthermore, management may be under a heavy handicap from a technical standpoint with rigid process-centered job designs when it must make changes in product designs.

But there is a further, and possibly even more crucial difficulty with the process-centered approach. After the job content has been specified, the worker is usually selected to fit the "job," and the trend is to give him a minimum choice, if any, of the methods he will use or the standards of performance he must meet, and of the situation in which he must work. Selection standards are generally set in light of this design of the job, and if used, various selection procedures are designed for these standards. Changes in the basic job design are commonly made without corresponding changes made in the selection procedures. Thus, after some process changes, the organization may find itself with workers who are no longer qualified to perform adequately in the job. And further, the effectiveness of the selection procedures will be altered to an unknown extent and subsequent newly hired workers may not be able to perform any better than could be expected through chance hiring. One final point is that unless a great deal more becomes known about the variables affecting the design of a job, it cannot be expected that very much will be understood about the effectiveness of personnel selection tools.

The worker-centered approach to job design gives major recognition to the personal characteristics of the individual. Of particular importance are certain psychological needs of the individual worker, and the necessity for him to be able to satisfy these needs in the working environment. However, non-technical people who are not knowledgable as to the possibilities for flexibility in the production process place great emphasis upon providing various means through which the worker can satisfy his needs, without any reference to the work content of his job. They maintain the work content intact and advocate changing aspects of the job situation, such as improving welfare and benefit programs, working conditions, public and labor relations, etc.

It is obvious that the nature of the work a person performs has considerable significance for him, for no other reason than that he spends so much of his life at his work. It is our contention here that the use of worker-centered approaches to job design may be valuable in alleviating a number of social problems in industry but that work content is a vitally important variable which can not be overlooked in the search for solutions. Continued attention to employee need satisfaction, in isolation from the nature of the job is probably not enough to meet long-term economic productivity requirements. Providing for the isolated criterion of need satisfaction has not been very helpful in practice nor has it helped a great deal to increase our understanding of the forces operating in the job situation to increase productivity. Research results indicate that job satisfaction is not necessarily highly related to productivity. It may be worthwhile to speculate whether this is because only immediate productivity is being considered, and perhaps it would be more highly related to economic productivity or total cost. Or is it because significant changes in productivity can be expected only by properly organizing and ordering all of the criteria affecting the job as a whole, i.e, using the job-centered approach?

Some Further Limitations of Current Job Design Practices

Upon analysis it appears that the process-centered and worker-centered approaches, and the resulting job designs, produce some complex difficulties for the industrial organization. The consequences of these approaches and current job design practices are highly routinized jobs with external (to the job) compensations. Some of the most wide-spread consequences of narrow specialization of labor have been to minimize the consequences of turnover, minimize the effects of any individual's poor work performance, and to minimize the dependence of the company upon the individual. We shall examine these briefly in turn.

By having jobs designed so that the work content is highly repetitious, has low skill requirements, and requires a very short training cycle, the company is well-protected from the consequences of labor turnover, absenteeism or scarcity. New employees can be put to work and attain acceptable rates of output very rapidly. Thus the probability is low that an employee who quits, or the unavailability of particular skills, will have much influence upon direct productivity of the company.

It is also clear that the absent individual employee is not likely to influence the productive output of the company very markedly. The company is protected from serious effects by having a job design which permits rapid, though temporary, filling of the position.

Thus the company is only slightly dependent upon the individual worker. And in achieving this independence the company effectively minimizes the only role the employee has, that is, to work productively. Yet, many industrial programs have been developed for the express purpose of telling the individual worker how valuable he is in the operation of the company. The worker is heavily propagandized about the importance and significance of his job. But it is highly probable that the worker may see a disparity between the actual contribution of his job and propaganda.

The net effect appears to be that the indicated and assigned roles of the workers, individually and collectively, are in conflict: individuals hear that their roles or jobs are important, but they do not see the importance in the jobs which they perform.

The worker-centered approach also gives rise to similar logical difficulties. If jobs are tailored to the needs and desires of the various individual employees in direct accordance with their

[7] Wood, A., Okum, M. L., "Job Rotation Plan that Works," **American Machinist**, 1946, Vol. 90, No. 9

various aptitudes, abilities, and skills, it becomes paramount to have on hand a full complement of people who have the ability to meet the work requirements. Inflexibility on the side of the workers is now the problem. They are frequently unwilling to let possessed skills lie fallow while they engage in learning less desired skills or ones of lesser significance. Participation methods unfortunately cannot directly overcome the lack of basic abilities and skills.

The Job-Centered Approach to Job Design

In the job-centered approach that we are proposing as a basis for research and development of a theory of job design, consideration is given to the question of how job content can be organized to satisfy the needs of the technical process, of the organization and of the individual worker in order to maximize economic productivity. In addition this approach is based upon the hypothesis that there is an organization-worker-job interaction and that therefore a job cannot be designed independently of the process, worker and organization variables. Changing any of these job design variables in isolation from the others may cause a decrease in economic productivity. In addition to the variables introduced by the technical process, the organization and the person, the job-centered approach to the job design requires the consideration of many other variables stemming from the interaction among them.

The concept of interaction, although recognized and discussed for some time now as a significant factor in obtaining the goals of an organization, has not had adequate exploration and consequently there is little available data about the variables related to job design phenomena. Although the importance of individual aspects of the job-centered approach has been recognized for some time (such as job satisfaction) they have had little effect on job design practice. The reasons for this are related to (1) those responsible for the design of jobs have in many instances lacked the background necessary for properly utilizing the information available, (2) the available data have not been presented in the form of job design theory, and (3) research conducted and results presented relate only to isolated aspects of the total problem of the worker and his job.

It is planned that a theory of job design when developed will provide the necessary integration of job-associated variables and their effect upon maximizing economic productivity.

Summary and Concluding Comments

In this paper we have been concerned with the development of job design theory and with elaborating the need for systematic studies of job design methods. The concept of job design was defined, and consideration was given to the need for principles of job design, the criterion

(Continued on Page 20)

A Reply to Professor R. O. Swalm's Article "Performance Rating Using The SAM Films".*

By Dr. Herbert Lynch

Herbert Lynch & Associates, 117 E. Third St., Charlotte, N.C.
Former Project Engineer—SAM Rating Project, the project responsible for the films

Prof. Swalm, quite understandably, took some of his material for his critique from the S.A.M. brochure "How to Use Performance Rating Films." This brochure contains severals errors, some mathematical, and some errors of definition. It was prepared for promotional purposes only and should not be used in conjunction with the films. Unfortunately this was not pointed out in the brochure.

Prof. Swalm rightly questions the wording (from the brochure) "up to 25%." This should read "the average attainment of qualified incentive operators (assuming a large group of employees) should be 25% above normal." Obviously, since reference is made to an average (a mean) individual attainment would vary both below and above the mean.

When using the films only the accompanying manual ("Manual of Performance Rating Time Values") should be used for data or instructions.

Prof. Swalm has a misconception about the "general delay allowances" or "general conditional allowances" mentioned in the manual. This allowance does *not* include delay allowance attributable to any specific operation, machine or process. Such an allowance is general in nature and common to all jobs. Examples are: foreman giving instructions, signing payroll, opening or closing window, etc. Actually, an allowance of this nature is usually so small that it might have been well not to menton it, as it does create misunderstandings. Still, many companies employ it. It is usually about one per cent (1%).

In view of the above statement, some of Prof. Swalm's conclusions become erroneous. If a company reduced machine downtime on a specific operation, the expected output should definitely increase. Such changes in standard time are not in any way associated with the use of the Rating Films.

Furthermore, the manual suggests that any company may very well justify a concept of proper performance either higher or lower than that "taught" by the films. This is discussed briefly on page 26 of the manual. Some of the justifiable reasons for a higher concept might be:

1. Carefully selected employees
2. Better than average working conditions (Prof. Swalm's air conditioned plant)
3. Pay rates higher than "going" rates

Prof. Swalm goes through a rather lengthy mathematical exercise to prove that standard time is independent of allowances used (i.e personal and "fatigue" allowances—let's forget the conditional allowance!). No doubt about that, the survey data proved it rather conclusively and the manual makes that point several times. While many people question the finding because it clashes with usual notions held about how rating is done, until someone can disprove the finding factually, I, for one, am going to believe the data rather than anyone's opinion.

Prof. Swalm makes another basic mistake in setting up the hypothesis that an operator is supposed to work 480 minutes (8 hours) divided by the allowance factor. Not so; most define the fatigue allowance as an allowance to offset the output decrement (supposedly) resulting from fatigue. We do not necessarily expect the operator to take time out and rest for the equivalent minutes that the fatigue allowance represents. Therefore Prof. Swalm's equations and conclusions are invalid.

Prof. Swalm, at the end of the article, proposed a modification of the procedure recommended by the manual. He would have us set up ratios of normal time (determined by the group of timestudy men) to incentive time (as listed in the manual). He maintains that such ratios should be a constant. He is quite right—if the company uses a *constant* fatigue allowance. However, his method is not usable by a group that uses fatigue allowances that vary from job to job, as the ratios should then vary. Moreover, the company using his suggested procedure would not find out how its concept of proper performance compares with the concept determined by the 1,200 timestudy men who took part in the survey.

*Performance Rating Using The SAM Films, by R. O. Swalm, Journal of Industrial Engineering, September, 1954.

How To Control Production Costs Through Proper Work Measurement

By Phil Carroll*
Professional Engineer

There are many ways that Industrial Engineers can help to control production costs. Most of us think immediately in terms of "techniques." For example, many of us act like timestudy was an end in itself. We consider incentive coverage as the goal.

To me, these are only means to an end. Our real objective is cost finding and cost control. In an effort to emphasize these objectives, I will attempt to bring out three related points. These are

1. How you effect production cost by what you call standard.
2. How cost changes with your definition of overhead.
3. How you control cost by work measurement.

WHAT DO YOU CALL STANDARD?

Many of us concentrate on the measurement of so-called direct labor. In a large proportion of our plants, this is only half done. Indirect labor is rarely measured. And in our cost finding, we carry out the direct labor costs to the fourth decimal place. Then accounting spreads the overhead with a shovel. Some rent high-speed machines to rearrange the punched hole cards to attain more reprorated reprorations. Others investigate electronic computers to do this faster. Our latest enthusiasm is directed toward "operations research." Tell me, how can we get any better answers out of these slot machines than we put into them.

Now, whatever you call standard time is what accounting uses. The cost people use your standard or its money equivalent as a divisor in computing overhead rate. They use it as a multiplier in figuring the overhead cost of your products.

As a result, your conversion cost is the sum of your standard plus your overhead cost. That means whatever mistake you make in standards setting turns out to be three, four or five times magnified. In addition, any error in one cost is the same error in some others. If five dollars too much is charged to one product, five dollars too little is charged to another.

To emphasize this point, let me bring out some errors that we Industrial Engineers cause. One common type I call mixing compensation with measurement.

MEASUREMENT VS COMPENSATION

When we think of wage incentives we may not have time standards at all. Many use incentives simply to pay more money for more pieces. The Halsey 50-50 plan is an example. Such standard times as are used with this plan are meaningless for cost control purposes. As you know, the cost varies with each different performance.

Piecework is another example of distortion. Money rates are faulty for two reasons. One is that the wage rates differ between types of work. The other is that what ever time may underline the piece work price is juggled repeatedly by negotiation.

TIME JUGGLING

Time may be juggled to pay people more or less money. Time may be negotiated in juggled piece rates. In other instances, the standard time has never been set.

Other forms of inconsistent times you find in the simplified "rate setting" methods. Too, standard times may be disregarded completely. For instance, the standard may be set as 80 percent of a machine capacity. In other cases, the standard may be set on the bottleneck in a group operation and multiplied by the number of people in the group.

A fourth variety is the lack of relation between the wage rate and the incentive pay. Some folks have used a variation of the 75-25 split premium. Others have done the same thing with the 1-for-1 plan. They have added wage increase after wage increase to the "hours worked." By this process, one plant I know of pulled down an original 1-for-1 plan to 57 percent sharing.

LABOR DOLLARS

All of these incentive devices are unrelated to work measurement. The compensation is determined by economics or negotiation. The base rates are being changed every day.

Money wages or earnings are not measures of work done. They do not measure productive output. That is obvious to you from your knowledge of job evaluation.

You can see that we cannot measure industrial conversion with a rubber yardstick. In different words, we cannot use labor dollars as a measure of productive output. What we need is standard time. So watch out if you're mixing compensation with measurement.

METHODS IMPROVEMENT

At this point you may say, "We don't do any of that juggling." Well, if you're progressive, you may cause another type of error. What happens when you make methods improvements?

In my experience, methods improvements take three forms. One results from the progress forced upon us from the outside. It takes the forms of better machines, better tools, and better handling devices sold to us by the folks who make them.

A second form shows up in what I call "rate setting." A timestudy man makes an effort to improve the job before taking his study. The degree of improvement depends to some extent upon what he ate for breakfast that morning.

The third form of method improvement comes in the drives we make to reduce costs. Educational meetings are held. Demonstrations are put on. "Everybody gets in the act."

WORK RELATION

In these three approaches, we improve one operation, one job, one process, one department, or one type of product. At any moment, one is greatly improved in relation to the others. What has happened to your cost divisor?

Part of your divisor has gone down. The other part remains unchanged. Your overhead rate has gone up. As a result of these changes you shift some of your overhead cost away from the improved jobs to the less efficient operations. That is illogical.

It happens because most plants use an average overhead rate. Let me demonstrate what takes place with an example.

PRODUCT MIX

Here we have an illustration of a shift in product mix. To keep it simple, I have shown only two products A and B. The total represents 100 percent of your volume. The percents of scrap representing normal in each case are the factors I am using to represent the overhead costs.

*Author of "Timestudy For Cost Control," "Timestudy Fundamentals for Foremen," "How To Chart Timestudy Data," and "How To Control Production Costs."

JUNE

Volume		Percent		Weighted
70	X	10	=	700
30	X	5	=	150
100				850

Average 8½

JULY

Volume		Percent		Weighted
30	X	10	=	300
70	X	5	=	350
100				650

Average 6½

You can see that when you carry out the extensions for the month of June, you get an average scrap of 8½ percent. Now in July, we assume that the volume remains at 100 percent. However, the percentages of products that make it up have interchanged. Product A is 30 percent and product B is 70 percent of your total.

If the average scrap were to drop, any manager would raise the flag. He would pat somebody on the back if it dropped 7½ percent. What should it fall to? Carry out the example, you see that it should be 6½ percent if you made no improvement whatever in performance. This is an example of the error in average thinking.

This shift in overhead was pointed out in the May 1954 issue of FACTORY. The article is entitled "Better Standards For Closer Cost Control." The problem relates to heat treating. And the author states, "Since the cost per furnace hour is approximately equal for processing each part, it's obvious that standards based on pounds of parts processed would be very inaccurate." What he is saying is that pounds do not measure work any more than dollars do.

GADGETS AND WIDGETS

Then there's another, more common distortion in our standards. Take a look at the condition caused by degrees of tooling.

Product	Quantity	Standard Mins.	Labor Cost @ $.90	Tool Cost
Gadgets	10,000	1.0	$150	$150
Widgets	1,000	2.0	$ 30	Zero

To make the point, we will use two products called Gadgets and Widgets. Gadgets are made in 10,000 lots. So we have tools to turn out more production efficiently. The cost of these tools is taken as $150. With tools, we have a standard per piece of 1.0 minutes each.

In contrast, let us assume that Widgets are made in 100 piece lots. With small lots, we say we cannot afford tools. In such instances, the usual timestudy man would set a standard that includes the time required for the method used. Here I assume a standard of 2.0 minutes per piece.

To portray the error in standards setting, I have omitted all overhead cost except those for the tools. So our overhead is equal to $150 plus zero.

To get your overhead rate, you would divide the $150 by your labor costs. At 90c an hour, labor cost for 10,000 gadgets is $150 and for 100 Widgets is $30. Labor cost equals (10,000 x 1.0 x $.015) plus (1,000 x 2.0 x $.015) or $180.

To get your overhead rate, you divide $150 overhead by $180 labor costs. That equals 83 1/3 percent. Now let us apply this percent to figure our overhead costs.

TOOL COST APPLIED

Gadgets	$150 LC	X	83⅓% = $125
Widgets	$ 30 LC	X	83⅓% = $ 25

You can see in this example how we have charged $25 for tools to Widgets. In the same process, we have charged only $125 to Gadgets. We know we spent $150. That was our starting assumption.

Where is our mistake? It is in our standard setting. The error is the extra 1.0 mins. allowed in the standard for Widgets. Commonly, we allow the extra 1.0 minute because we lack the tools. We forego making tools because it is cheaper to whittle out the small quantities. Yet the extra 1.0 min. is tool cost just the same, spent as labor because it is cheaper than tools. So to correct the error, you should report the extra one minute as overhead. If we do that, the new overhead rate works out to be 100 percent.

$$\frac{\text{Tool Overhead}}{\text{Labor Cost}} = \frac{\$150 + 1{,}000 \times [illegible] \times 0.15}{(10{,}000 + 1{,}000 \times 0.15} = 100\%$$

Now when you apply your overhead rate to your labor costs for the two products, your answers come out correct.

TOOL COST APPLIED

Gadgets	$150 LC	X	100% = $150
Widgets	$ 15 LC	X	100% = $ 15

Of course, this problem is rigged. It would not work out exactly right otherwise. The point is that you would not make tools unless you gained an overall saving.

MANAGEMENT ERRORS

Now let's take up a third type of standard setting error. My name for this form of measurement dilution is "Management Error." It is like the condition referred to earlier in methods improvement.

It is the burying of indirect labor in so-called direct. But it includes also the different types of waste time. Two common examples are "Temporary rates" and allowances like unavoidable delays and interference factors. You might choose to add arbitration awards.

WHAT DO YOU CALL OVERHEAD?

Let me see if I can show you how your overhead rates depend upon what you call overhead. Take a simple case.

$$\frac{\text{Overhead}}{\text{Wages}} = \frac{\$2.00 \text{ Overhead}}{\$.50 \text{ Direct} + \$.20 \text{ Waste} + \$.30 \text{ Indirect}} = 200\%$$

When you look at such an example you say, "Waste time is overhead?" I reply, "All right, let's move it." Now what is your overhead rate?

$$\frac{\text{Overhead}}{\text{Wages}} = \frac{\$2.00 \text{ Overhead} + \$.20 \text{ Waste}}{\$.50 \text{ Direct} + \$.30 \text{ Indirect}} = 275\%$$

But let me ask you. "Do you recognize as waste such things as unavoidable delays, waiting time and interference factors?" Notice that whatever you put in your standards alters your denominator. By the same token, what you omit from your standards should be included with your overhead. Both change your overhead rate.

More than that, with average overheads, you get the wrong operation or product cost when you multiply back. You shift your overhead to your less efficient operations. In so doing, you fail to apply your overhead to your more efficient operations.

WHAT IS INDIRECT?

Now let's take the next step. With indirect so labeled, you may say that it should be treated the same as waste. So you transfer the $.30 indirect to your overhead. What is your new overhead rate?

$$\frac{\text{Overhead}}{\text{Wages}} = \frac{\$2.00 \text{ Overhead} + \$.20 \text{ Waste} + \$.30 \text{ Indirect}}{\$.50 \text{ Direct}} = 500\%$$

Note, all these costs are the same costs. All we have done is to arrange them differently.

Now what is indirect? What is overhead? With labels, you know where the costs belong in accounting. But do we recognize "indirect" in the shop? Is setup direct or indirect? Do you allow it separately? Do you prorate it? Do you use different standards for lot sizes?

Do you use "temporary rates?" Do you have, "For this run only rates?" How about too much stock on your castings? What do you do about poor quality workmanship from previous operations? Where do you show all the extra fitting and filing at assembly?

Is any of this extra work direct labor? Do you get any extra pieces for the extra work? Can this extra work actually earn any overhead?

OUR INEFFICIENCES

One Controller said, "We earn our overhead on our inefficiencies." In reply, I suggested, "You mean you apply your overhead to your inefficiencies." That incident summarizes this whole series of errors. To repeat, the accountant uses the standards as we set them. He uses them to figure his labor costs. Then he applies his overhead rate to these labor costs.

Consequently, I think that Industrial Engineers have a grave responsibility. They are the only ones who can set up the correct foundation for measuring production costs. They are the ones who must establish the common denominator for the wide variety of mixtures we have in industry. That reminds me of a story. A young lad came to his father and said, "Pop, can you help me find the least common denominator?" His father looked at him in amazement and asked, "Son, haven't they found that yet? They were looking for it when I was a boy."

Industrial Engineers must sort the productive from all other kinds of so-

called labor. Productive labor is the one that is equivalent to good, saleable pieces. But the problem is even more complex. Let me point out another big factor.

EVERY ADVANCEMENT IN MANAGEMENT

Let us take a look at some of the enormous errors we can make in our use of overhead rates. I cooked up the following examples to show our cock-eyed thinking in overhead rates. Let us start with a simple ratio of overhead to labor.

$$\frac{\text{Overhead}}{\text{Labor}} = \frac{\$150{,}000}{\$100{,}000} = 150\%$$

Now suppose we begin some advancement in management. Assume we introduce timestudy. Right away, our overhead dollars are increased. If the timestudy men get some results, your labor devisor is reduced and your overhead rate has jumped to 200%.

$$\text{Plus Timestudy} = \frac{\$150{,}000 \text{ plus } \$10{,}000}{\$80{,}000} = 200\%$$

As you would expect, Timestudy shows the need for better planning. So we add some planning to our overhead dollars. Better scheduling saves some lost time. Now what happens to your overhead rate?

$$\text{Plus Planning} = \frac{\$160{,}000 \text{ plus } \$10{,}000}{\$65{,}000} = 261\%$$

Then, suppose we see the need for methods improvement. So you assign some people to think up better ways, devise jigs and fixtures, perhaps buy some new machinery. The result is that your overhead dollars have increased still more. Relatively, however, your direct costs come down. Look what has happened to your overhead rate.

$$\text{Plus Method} = \frac{\$170{,}000 \text{ plus } \$10{,}000}{\$50{,}000} = 360\%$$

Contrary to these examples, as you know, our improvements usually result in expansion rather than reduction of labor payrolls, but I chose this form of showing relations to keep out volume change.

CLERICAL COSTS

The problem of overhead costing is a great deal more complicated than these simple examples indicate. Take another angle. How much does it cost you to run an order through your "paper mill." Perhaps as much as $4.75 each. If that is about your cost, how can you make money selling a spare part for $.25 each. You lose $4.50 on every order.

Think of this in a different form. One plant investigated the breakeven point on an order. Obviously, this varies with two things. One is the cost to process the order. The other is the profit margin in the goods sold. Regardless, this company found that for one given product, it required $85 worth of sales to break even on an individual order.

Moving on, what about specials? Who pays for the extra engineering? Do you collect for the extra set ups? Do you make money when your Works Manager chases the hot job? Most folks would have to answer "No" to these questions. They might say, "We make out on the average." Others say, "We cannot measure the indirect. It costs too much money." That brings me to my third and last point.

COST PER STANDARD

"Too expensive" has two sides to it. One is that you cannot control costs unless you have some kind of measurement. I think also that you need incentives. That is another subject.

The other side depends upon how much it costs you to set a standard. Many say that "Timestudy costs too much" because they think in terms of rate setting To set one standard from a single timestudy costs about seven times as much as it does to set standards from standard data. But I am not thinking of reducing the number of timestudy men. My answer to the question, "How many timestudy men should we have?" is "Whatever the number, double it." What I am thinking about is to increase the amount of work measured per timestudy man. I'm thinking about methods improvement in timestudy. And I know that if you will chart your data, you can make a helluva cut in your cost per standard.

One man I know reduced the time to set a standard from 25 to 6 minutes by means of charts. Another eliminated 30 calculations with one chart. A third reduced the time to set a standard from 90 to 2 minutes.

CHART YOUR DATA

Let's take a quick look at three simple devices you can use to save time. The first is to make your standards "direct reading." What I mean is to make your charts so that you can go directly from the dimensions you must use to the standard time without making calculations. A simple example occurs in the foundry. Usually, you want the area of a flask and its volume. You start with length, width and depth. Make up a chart that has length as one of the variables, width shown in the body of the chart and the area on the outside as the other variable. Knowing the area, you can substitute the standard time for "Strike Off."

Having arrived at this point, you can extend the chart to include the depth of the flask and thus compute the volume. Now, you can substitute standard time for "Fill Mold with Sand." Thus, you build up a direct reading chart that goes from length, width and depth to standard times for "Strike Off" and "Fill Mold With Sand."

The second way you should look into is the means for combining charts of variables. Find how to make multi-variable charts that will combine many variables and constants.

A third improvement you should consider are the ways to reduce clerical work, errors, and decisions. Try to set up your working data, in what you might call a "Form." If possible, get all your working data on a single 8½ x 11 sheet. Try to arrange your values so that the only clerical work consists of circling standard times and setting out the extensions. This will save you clerical work. It will reduce the errors of transportation in copying from one sheet to another.

Perhaps your greatest saving is made in reducing the number of decisions that have to be made. This improvement comes about through the clarity of definitions you use in recording your data. Define the borderlines between increments of data by using numbers. Rule out all interpolations.

WHAT TO DO

The points I have tried to make might be summarized in three groups. First, I have tried to show that we need to properly measure work. We should separate waste time from productive time. We should separate indirect from direct labor. These steps are necessary in order to get a measure of saleable output. If we made one style, one size, and one color of product, the saleable output would be obvious. But very little industry is that simple today. Therefore, I maintain that we must separate actual productive work from all other kinds of work to provide a sound common denominator for cost control.

Secondly, I have tried to show how the wrong denominators cause wrong overhead applications. Yet with a perfect denominator of saleable output, your overhead costs may still be wrong. Average overhead is wrong for mixed products. To overcome this error, I think we should do two things. One is to break down our overhead expenses to the products that cause them. The other is to study your overhead expenses, reduce them, and set standards to measure the work that should be done.

For such purposes, budgets are no good. They customarily apply to functions in the organization, not to the products made and sold. Besides, most budgets define neither the amount of work to be done nor how often it should be done.

Third, I tried to emphasize that we should measure more of the work than we do to improve the control of it. By this I mean that we should measure all of the direct and all of the indirect labor. This will call for faster and cheaper methods of standard setting. We can make many improvements in this direction. I have suggested that we use standard data in place of direct timestudy and that we use charts to save time, errors, and decisions.

Wrapping this all together, we can say that the way to control production costs through proper work measurement is to do more and better work measurement.

Methods Improvement In The Office

By H. T. Amrine

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Based on a Talk Presented to Cincinnati Chapter, AIIE, Jan. 20, 1954

There is clear cut evidence that the efficiency in the typical office has not kept pace with the efficiency of the production line. One need but visit a few companies to get visual proof of this fact, and yet, a dollar saved for labor in the office is just as valuable as a dollar saved for labor in the shop. Failure to recognize this simple truth is costing many American businesses countless dollars in needless administrative expenses.

Careful analysis, of many offices, will disclose an unbalanced increase in paper work and the number of clerical workers as compared to production workers. The ratio of office workers to production workers has continued to increase through the years, until now about one out of every 6 industrial employees works in the office. This increase can be attributed to several factors: (1) the increased paper work and record requirements imposed upon the business by Government, (2) increased personnel activities and employee services, (3) increased controls, (4) the shortage of skilled office help, and (5) inadequate efforts to control the growth of the office staff.

Even though many managements are eager to reduce office costs, few of them seem to realize the full value and potentialities of an office methods-improvement program. This is true, even though as L. L. Purkey[1] has pointed out, "Too frequently, adequate measurements reveal that from one-third to one-half of all administrative, accounting, and clerical activity, characterized as paper work, falls into the following categories:

Useless and outmoded communications and reports;
Duplicated records made and maintained in the same organization;
In case records to establish future claims of accomplishment or in anticipation of questions never asked;
Excessive analyses and statistics employed as substitutes for individual courage and sound judgment;
Poorly designed records which are basically necessary but are encumbered with extraneous and costly information of little use to anyone;
Information assembled to satisfy technical curiosity but having no practical value.

Further, Purkey states, "Most work can be simplified. This is particularly true of procedures related to adminstrative, accounting and clerical activities. Much has been accomplished over three decades in factory and other operating methods and procedures, but only limited progress has been made in discarding or replacing outmoded paper systems, the elimination of unneeded work and detail, the simplification of essential records and reports, and work measurement as a basis for manpower control. In this connection the opportunities for cost reduction are seldom fully recognized."

It is quite obvious that unless office methods are analyzed critically, they may never be improved. Too many routines are continued year after year simply because they are considered adequate and no one questions them. And yet as Herrmann[2] states, "it is generally agreed that the money spent for the services of a full-time methods man can be a profitable investment in an organization having as few as twenty-five clerical employees." It is high time then that more of these methods men appear on the scene of action.

At the outset of any methods improvement or work simplification program, it is not uncommon to meet with some resistance. This is perhaps true to a greater extent in the office than in the shop. However, recognition that barriers exist will help one to surmount or circumvent them. The common barriers which one might anticipate encountering in the office methods improvement program include:

1. Lack of top management interest — top executives commonly do not appreciate the value of work simplificaion in the office.
2. Much of the office inefficiency is hidden in the multitude of papers, reports and records.
3. Supervisors have often never been taught to be cost conscious and are not cost minded.
4. Long time, inefficient habits have been developed which are difficult to overcome.
5. Supervisors usually have not been trained in the principles of Work Simplification and have a lack of "know how."
6. The desire for self protection results in building excessive controls.

Then too, there are the usual factors of:

7. Resistance to new ideas and methods.
8. Resentment of criticism.
9. Lack of imagination.
10. Fear of unemployment.

All of these factors make it necessary to plan the methods improvement approach very carefully. We must give consideration to the human aspects of the program, and, in this regard, it will be wise to heed the advice of Roethlisberger and Dickson[3], who suggest that, "In introducing technical change, it is important: first, that the sentiment of the people directly affected be determined; secondly, that the sentiments of other people related to them be determined; thirdly, that problems arising from the new pattern of interpersonal relations be anticipated and understood; and finally, that an understandable and acceptable explanation of the change be made before it is introduced."

This is in keeping with Zander's[4] recommendation that, "Resistance will be prevented to the degree that the changer helps the changees to develop their own understanding of the need for the change, and an explicit awareness of how they feel about it, and what can be done about those feelings."

We must recognize that participation tends to breed acceptance and that the maximum benefits from any methods improvement program are derived from the contributions of many. It behooves us then to have the office supervisors and, if possible, the office workers actively participate in the program. And this is where the Industrial Engineer can play an important role. Analysis of most office methods improvement or work simplification programs will disclose that they are basically methods studies and the adaptation of motion study techniques to the office. Then, why not let the Industrial Engineers take an active part in the program by training the office supervisors and the clerical workers in the fundamentals of work simplification? The objectives of this program should be to:

1. Reduce paper work by reducing the number of forms, reports, records and procedures.
2. Provide greater controls.
3. Eliminate waste materials and manpower.
4. Reduce the time and distance required to process paper work.
5. Improve the office and work place layout.
6. Increase workers' comfort.

In establishing the content of the total office methods improvement program, consideration should be given to each of the following:

1. Organization analysis.
2. Job analysis.
3. Work distribution.
4. Reports and forms analysis.
5. Work simplification.

Organization analysis is extremely helpful because it facilitates following the lines of supervision, responsibility and authority. It tells "who does what for whom." If the organization structure is unconventional or unwielding, it may point to major organizational changes. Although the Industrial Engineer, traditionally, has not taken an active part

[1] Joseph W. Lucas, "More Profit-Less Paper Through Work Simplification," Department of Organization, Standard Oil Company, San Francisco, 1953, page 1.

[2] I. A. Herrmann, "Office Methods, Systems, and Procedures," The Ronald Press Company, New York, 1950.

[3] F. J. Roethlisberger and W. J. Dickson, "Management and the Worker," Harvard University Press, Cambridge, Massachusetts, 1950, page 58.

[4] Alvin Zander, "Resistance to Change—Its Analysis and Prevention," Advanced Management, Vol. XV, No. 1, January 1950, page 9.

(Continued on Page 22)

Machine Replacement Analysis

By R. O. Swalm

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Several years ago a young British executive, upset by persistent derogatory comments on British machine replacement policies by visiting U.S. experts, came to this country to determine the replacement policy used by American firms. He returned a disillusioned man—for he found no policy in many firms and lack of agreement on correct policy in the remaining firms.

Why should this be? Surely our present emphasis on lower costs in order to meet growing competition demands an accurate analysis on which to build a valid replacement policy. That this is increasingly realized is indicated by the growing interest in the MAPI formula developed by George Terborgh. Relatively few companies, however, are using Terborgh's approach to machine replacement policy—and those that are not are using a wide variety of alternatives.

It would therefore seem appropriate to evaluate a number of the more common techniques used in replacement analysis.

This, of course, is easier said than done. A theoretical evaluation becomes lengthy and difficult. An empirical approach is less rigorous and less conclusive—but has the great advantage of being far simpler and shorter. It is therefore the approach that we propose to use here.

W. E. Deming, in *Statistical Adjustment of Data*, says, "Simple problems are always best for illustration; if we can understand the simple problems, there is some hope that we can understand the more complicated ones."

Taking our cue from this, we will describe a simple machine replacement problem. We will then obtain a solution to the problem by employing four widely used techniques of machine replacement analysis. We will find that these techniques yield differing results, and therefore cannot all be correct.

It will therefore be necessary to determine which, if any, of these solutions is correct. We can do this by a direct method because of the simplicity of our problem. Having done so, we will re-examine the techniques that yielded incorrect answers to find the error in their use.

We will not examine all the techniques ever used. Nor will this type of approach yield a proof that the technique shown to be correct in this case will be correct in all others. It is hoped, however, that we will be able to demonstrate conclusively the fallacies in several widely-used techniques and indicate that others should be used with caution if they yield an incorrect result in at least one special case.

The problem to which we shall address ourselves is this:

> A manufacturer required soft water for a certain process. Acting on the advice of a hardware dealer who was a friend of his, he put in a series of water softeners designed for home use at a cost of $7,000. He was surprised to find, at the end of the year, that operating costs had amounted to $900, and commented on this to an engineer who happened to be visiting him. The engineer examined the installation and concluded that the hardware merchant had given very poor advice indeed. He also found that the original installation had been assigned a seven-year depreciation period, since a municipal water softener was to be installed at the end of that time. Despite the fact that the softener would be required only six more years, the engineer proposed to the manufacturer that a properly designed installation be purchased for $4,200. The salesman for this installation was willing to offer an allowance of $1,800 for the old softeners, removing them at his own expense. This was felt to be the maximum amount realizable on them. The new installation would be guaranteed to cost no more than $400 per year for operating costs. It was estimated that either the present or new installation would have no net salvage value at the end of six years. Neglecting interest charges and income tax considerations and assuming the new installation would cost just $400 per year for operating costs, should the manufacturer accept the engineer's advice?

Here then is our problem. What results would we obtain by applying several of the more common approaches to the solution of machine replacement problems?

APPROACH # 1

One of these approaches is that the savings obtained by the installation of the new asset must be great enough to pay for the new asset plus the loss of book value on the old asset. This we will call approach number one.

Solution (APPROACH # 1)

In order to use this approach to determine whether or not the new softeners should be purchased, we must first calculate the total savings obtained by installing the new softeners. This saving will be the difference in operating costs times the number of years over which such savings accrue, or

TOTAL SAVINGS=
($900/year—$400/year) x 6 years
or TOTAL SAVINGS=$3,000.

Are these savings enough to pay for the cost of the new softeners plus the loss on book value if the old softeners are sold?

The cost of the new asset is stated as $4,200; the book value on the old will be given by the accounting equation

BOOK VALUE=FIRST COST—ACCRUED DEPRECIATION

Assuming straight line depreciation, the accrued depreciation will be given by

$$\text{ACCRUED DEPRECIATION} = \frac{\text{FIRST COST}}{\text{LIFE}} \times \text{YEARS SINCE PURCHASE}$$

or

$$\text{ACCRUED DEPRECIATION} = \frac{\$7{,}000}{7} \times 1 = \$1{,}000$$

Therefore, the book value will be $6,000 and the loss on book value will be $6,000 Book Value less $1,800 Salvage Value, or $4,200.

The amount to which the total savings is to be compared is therefore the sum of the cost of the new asset ($4,200) and the loss on book value ($4,200), or $8,400.

Conclusion (APPROACH # 1)

The manufacturer could lose $8,400 less $3,000, or $5,400 by installing the proposed equipment.

APRPOACH # 2

A second approach commonly used is of the general nature of, "Purchase the proposed equipment if it will pay for itself in four years." What result does this approach yield?

Solution (APPROACH # 2)

The cost of the proposed equipment, using this approach, would be $4,200 less the $1,800 allowance, or $2,400.

The savings obtained in four years would be $500 per year times four years, or $2,000.

Conclusion (APPROACH # 2)

Since the proposed equipment will not meet the stipulated pay-off period, it should not be purchased.

APPROACH # 3

A third approach, being used with increasing frequency, is to apply the MAPI formula. This formula was first published in George Terborgh's pioneering work, *Dynamic Equipment Policy*, (McGraw-Hill), and later its recommended use was modified somewhat in the *MAPI Replacement Manual*, published by the Machinery and Allied Producers Institute. Since the manual requires 75 pages to explain the use of the formula, it is obviously impossible to do the same in a few short sentences. Therefore, we propose to use the "cook book" approach here—that is, to simply follow, on faith, the method proposed in the manual. To do this it will be necessary to follow

closely the somewhat unfortunate terminology found in that manual.

Solution (APPROACH # 3)

Using this approach, we must first obtain the operating superiority of the challenger (or new machine). This is the same as the operating inferiority of the defender (or old machine), and is defined as difference between their operating costs each year, or $500.

We next obtain the capital cost of the defender. This consists of the decline in salvage value. The decline in salvage value in the coming year is not given in the statement of our problem—but since we know that the salvage value is $1,800 now and zero in six years, a logical assumption would seem to be that it will decline by one-sixth of $1,800, or $300. Since we are neglecting interest, there will be no interest charge on the present salvage value.

In the MAPI approach, the adverse minimum of the defender is defined as the sum of its operating disadvantage ($500) plus its capital cost ($300), or $800.

This is to be compared to the adverse minimum of the challenger. To estimate this, we must first estimate the probable life and terminal salvage value of the machine. We then calculate the "terminal salvage ratio" by dividing the terminal salvage value by the first cost. (In our problem the probable life is six years, the salvage value is zero, and therefore the terminal salvage ratio is zero.

Instructions for using this method call for us to enter the MAPI chart with the estimated life and terminal salvage ratio to find what is called the "the chart percent." To this is added the interest rate assumed, and the resulting total percent is applied to the installed cost to give the adverse minimum of the challenger.

For our problem, we enter the chart with a six year life and zero salvage ratio and obtain a "chart percent" of 26.5%. To this we add our assumed interest rate of zero, and apply the resulting "total percent" of 26.5% to the first cost of $4,200 to obtain challenger adverse minimum.

Conclusion (APPROACH # 3)

Since the challenger adverse minimum ($1,100) is greater than that of the defender ($800), replacement is not indicated.

APPROACH # 4

A fourth approach might be that proposed in such texts as Grant's *Principles of Engineering Economy* (Ronald) or Thuesen's *Engineering Economy* (Prentice-Hall). In this approach, we compare annual costs, considering the value of the existing equipment to be its salvage value (the book value is considered irrelevant), and the present value of the new asset to be its total purchase price.

Solution (APPROACH # 4)

This approach sets up a tabular comparison shown in Table 1.

Table 1

Source of Expense	Cost per Year If: Old Asset Is Retained:	New Asset Is Purchased:
Depreciation	$\frac{\$1,800}{6 \text{ years}} = \$300$	$\frac{\$4,200}{6 \text{ years}} = \$700$
Operating Costs	$900	$400
TOTAL ANNUAL COSTS	$1,200	$1,100

Table 2

Approach #	Purchase New Equipment	Why
1	No	Lose $900/year
2	No	Will not pay for itself in four years.
3	No	Lose $300 the first year
4	Yes	Save $100/year

Table 3

Source of Expense		Actual Dollar Outlay If Old Softeners Are Retained	Actual Dollar Outlay If Proposed Softener Is Purchased
Past Expenditures	Original Investment	$ 7,000	$ 7,000
	1st Year Operating Cost	900	900
Time of Decision			
Expenditures Affected by Decision	New Investment		2,400
	2nd Year Operating Cost	900	400
	3rd Year Operating Cost	900	400
	4th Year Operating Cost	900	400
	5th Year Operating Cost	900	400
	6th Year Operating Cost	900	400
	7th Year Operating Cost	900	
	TOTAL EXPENSES	$13,300	$12,700

Conclusion (APPROACH # 4)

A savings of $100 per year for the next six years can be obtained by installing the proposed asset.

Summarizing the results of each of these four approaches we have Table 2.

We see from the second column that we have obtained two different qualitative answers — and therefore conclude that at least one of these approaches must be incorrect. Further, we would suspect from the variations in the last column that not more than one of them can be correct.

How can we determine which, if any, of these approaches leads to the correct answer? In this simplified case it is not difficult — we have only to add up all out-of-pocket expenses that have occurred or will accrue from the inception to the assumption that we keep the old softeners and also under the assumption that we trade them in on a new installation, as suggested by the engineer. The alternative having the least total cost is obviously more desirable.

We first note that the actual expenditures to date have been $7,000 first cost plus $900 operating costs for either alternative. If we retain the old equipment, expenses will be $900 per year for the next six years.

If the new equipment is purchased, and immediate outlay of $2,400 ($4,200 less $1,800 allowance on old equipment) must be made, and annual expenses for the next six years will be $400 per year.

Our comparison of all out-of-pocket costs for the entire period in which we require water softeners is, therefore, as as shown in Table 3.

Discussion

The installation of the new softeners will result in a savings of $13,300 less $12,700, or $600. This represents a savings of $\frac{\$600}{6}$, or $100 per year for the remaining six years.

Comparing this result to that obtained by the four approaches used above, we see that, for our problem, only approach number four yields the correct qualitative or quantitative answer. We must face the fact that, no matter how convinced we might be that one of the other approaches is "correct" that, in this particular case, it yields an incorrect answer. There must, therefore, be a fallacy in its use to solve this particular problem.

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Travel Charting—
FIRST AID FOR PLANT LAYOUT

By Wayland P. Smith

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If you have been looking for a useful charting technique to help solve your plant layout problem, this might be the answer. If your problem is one that involves a process or colony type of layout where similar machines are grouped together, this technique is bound to be helpful. Or, if your problem involves processing different parts through the same line of machines where the sequence of operations differs for some of the parts, this technique will give you answers in a hurry.

Travel charting is a technique which can reduce a large quantity of data into a very compact form so that it may be more readily analyzed. Travel charting can make sense out of apparent nonsense in many instances. Travel charting can graphically point out material handling inefficiencies, such as backtracking, and indicate potential bottlenecks where special attention may be required. Travel charting makes it possible to actually measure how efficient your layout is with respect to material handling.

Just what is a travel chart?[1] In appearance a travel chart looks very similar to mileage charts that you will find on most road maps which indicate how far it is to and from a large number of cities. In the travel chart we list machines or machine colonies instead of cities. Also, instead of filling in the squares with mileage distances we indicate the amount of handling which takes place from one colony of machines to the next. (See charts below.)

Mileage Chart

To \ From	Chicago	Cleveland	New York	Pittsburgh
Chicago				
Cleveland	350			
New York	800	450		
Pittsburgh	500	150	300	

Travel Chart

To \ From	Raw Mat'l.	Lathes	Mills	Assembly
Raw Mat'l.				
Lathes	50		25	30
Mills	20	5		40
Assembly	40	100	40	

In actual practice the figure entered may indicate more than the frequency of handling. It might also factor in the weight of the part, the bulkiness of the part, or any other factor that would be pertinent to the problem.

There are some other important differences between these two charts that should be noted.

(1) On the mileage chart nothing appears above the diagonal line. Actually, we could enter numbers here, but it would simply be repeating facts that were already known. For example, if we know it is 350 miles from Chicago to Cleveland, it will also be 350 miles from Cleveland to Chicago. Therefore, to repeat these figures is unnecessary.

However, such is not the case for the travel chart. Here anything that appears above the diagonal line indicates *back tracking*. A cursory examination of the chart will show why. When the colonies were listed both at the top and side of the chart, they were listed in the sequence that was considered most desirable. This sequence is the same from right to left as it is from top to bottom. Therefore, if any part moves in a direction opposite to this sequence, it will show above the diagonal line.

(2) It should, also, be noted that there is real significance in the distance that separates a number and the diagonal line on the travel chart. If the number appears in the square just beneath the diagonal line, it indicates that work is flowing directly from one colony to the next. However, if the number appears two squares beneath the diagonal line, it indicates that this work is skipping over one colony. It can be seen that the *ideal* condition would be to get all of the numbers to appear in the squares immediately beneath the diagonal line. This would mean that all of the work would flow directly from one colony to the next until it was completed and that there would be no backtracking. The ideal can be approached by two methods.

a. Changing the arrangement of the colonies.

b. Changing the sequence of operations on the parts that are giving you trouble.

(3) One other item that serves as a helpful check upon the accuracy of the data is that each column of vertical numbers must total to the same amount as the corresponding horizontal column. It should be apparent that the number of jobs going into the lathe group, for example, must be equal to that leaving the lathe group. Otherwise some items have been lost in the charting process, or errors have been made in transposing the data. There is an exception to this that should be noted. The first and last stations do not balance in this manner. However, the *sum* of the first and last columns on the horizontal should always equal the *sum* of the first and last columns on the vertical. An examination of the chart will reveal why this is true.

Travel Charting Procedure

(1) Define the assumptions upon which the study will be based.

(2) Collect the necessary data.

(3) Arbitrarily select an arrangement of colonies that appears desirable (or use the existing arrangement).

[1] D. C. Cameron, "Travel Charts," **Modern Materials Handling Magazine**, January, 1952, page 37.

(4) Treat the data (2) according to the assumptions that have been made (1) and post this information on the travel chart.

(5) Analyze the travel chart and determine both the ideal and actual efficiency of the system.

(6) Make improvements by changing the arrangement of the colonies or by changing the operation sequence of individual parts.

(7) Post the revised information and repeat Steps 5 and 6 until the most efficient arrangement is attained.

A Simple Example

(This is a greatly simplified example of an actual problem that the author worked on at the Lincoln Electric Co.)

The problem was to determine the optimum arrangement of a group of machines used to process a large number of different parts where the sequence of operations on these parts was different.

(1) Definition of Assumptions.
- 1.1 The yardstick used to measure the effectiveness of the layout will be the sum of the products of the mass of each part multiplied by the distance moved.
- 1.2 The distance between the work stations will be considered equal.
- 1.3 Back-tracking will be considered *twice* as bad as moving work forward.
- 1.4 Changes in operation sequence of individual parts will be considered impossible.
- 1.5 The analysis will cover *all* parts that are known to be processed through this group of machines.

(2) Collection of Necessary Data.
- 2.1 The machines in this group are:
  - A. square shear
  - B. punch press
  - C. milling machine
  - D. paint booth
  - E. welding booth
  - F. cut-off machine
  - G. turrent lathe
  - H. surface grinder
- 2.2 The parts, volume, and sequence data are shown in Table 1.

(3) Selection of an initial machine arrangement
- 3.1 Incoming storage
  A-B-C-D-E-F-G-H
  Outgoing storage

(4) Treatment of data and posting of information
- 4.1 The data was treated previously in Step (2) and converted to wt x 10^4/mo to conform with assumption (1.1).
- 4.2 See Table 2.

(5) Analysis of travel chart
- 5.1 Determination of 100% efficiency. From assumption (1.1) this would be the minimum sum of the product of wt x 10^4/mo multiplied by distance moved. This would be at a minimum if each move were from one machine to the next adjacent machine. Therefore, 100% efficiency can be computed as shown in Table 3.
- 5.2 Determination of actual efficiency.
  This determination is made by summing up all of the numbers which are the same unit distance away from the diagonal and multiplying this value times the unit distance from the diagonal. This is similar to calculating the moment of a group of weights about a line.

It should be noted that the total volume (402.2) is exactly the same as the calculated 100% efficiency for this system. Since this is always true, it is never necessary to compute this value separately as was done earlier because it can be readily computed at the same time that the actual efficiency of the system

Table 1. Parts, Volume and Sequence Data.

Part No.	Wt/pc	Pcs/mo	Wtx10^4/mo*	Sequence
1	5	2,000	1.0	A-B-E-H-D
2	10	10,000	10.0	G-C-H-D
3	4	2,500	1.0	B-H-C-E
4	20	20,000	40.0	E-C-H-D
5	3	15,000	4.5	A-E-D
6	8	5,000	4.0	F-G-C-H
7	12	9,000	10.8	C-H-D
8	10	12,000	12.0	B-E-H-D

*The decimal point has been shifted here because it gives a number that is more convenient to use.

Table 2. Data posted on the Travel Chart.

To \ From	In	A	B	C	D	E	F	G	H	Out	
In											0
A	5.5										5.5
B	13.0	1									14
C	10.8					40		14	1		65.8
D						4.5			73.3		78.3
E	40	4.5	13	1							58.5
F	4										4
G	10						4				14
H			1	64.8		13					78.8
Out					78.3	1			4		83.3
	83.3	5.5	14	65.8	78.3	58.5	4	14	78.8	0	

Table 3. Calculation or 100% Efficiency.

Part No.	Wt. x 10^4/Mo	No. of Unit* Moves	Wt. x Dist.
1	1.0	6	6.0
2	10.0	5	50.0
3	1.0	5	5.0
4	40.0	5	200.0
5	4.5	4	18.0
6	4.0	5	20.0
7	10.8	4	43.2
8	12.0	5	60.0
	TOTAL =		402.2
	100% efficiency = 402.2		

*Since it was assumed that the machines are all equidistant, it is not necessary to know the actual distance in feet.

is being computed.

The efficiency of this system is

$$19.4\% \quad (E = \frac{402.2}{2071.8} \times 100).$$

(6) Improving the system

6.1 According to assumption (1.4), the only method of improving this system is to re-arrange the machines and work stations.

6.2 Study of the travel chart prompted the following revisions:

A. Position the paint booth (P) last.

B. Position the surface grinder (H) in front of the paint booth.

C. Position the milling machine (C) in front of the surface grinder.

D. Arrange the other machines in this order: F-A-B-G-E.

6.3 These changes were made to eliminate back-tracking and to minimize long forward moves.

(7) Posting the revisions

Based upon these revisions, a new travel chart can be made, as shown in Table 5.

It is apparent just from examination of this travel chart that substantial improvement has been made through these revisions.

The actual improvement is quantified in Table 6.

The efficiency of this system is

$$58.6\% \quad (E = \frac{402.2}{685.7} \times 100).$$

This is an improvement of 32.2%.

If the distance between work stations were 15 ft., this would mean a monthly savings of 20,791.5 ft-lb of material handled.

It is possible that further improvements could be made on this system. In any event, they could be tried and tested against this revision to determine whether or not there actually is improvement.

Another Example

While working for the General Electric Company in Fort Wayne, Indiana last summer; this charting technique was used on a slightly different type of problem. In this case we were setting up a proposal for a new department for the manufacture of special machines and equipment for the Fractional Horsepower Motor Department. Since equipment of this type had been built on a limited basis in scattered areas of the Fort Wayne Works, it was possible to obtain a substantial quantity of data about the processes used to manufacture the component parts for these special machines and the sequence of these operations.

This data was treated and developed into a travel chart which was extremely useful in making the proposed layout. On this travel chart machine colonies are listed. One of these charts is shown on Page 26 as Table 7.

Table 4. Determination of Actual Efficiency.

Dist. From Diagonal, (Units)	Total Volume		Moment	
	Below (Forward)	Above (Backward)	Below (Forward)	Above (Backward)
1	14.5	4.5	14.5	9.0
2	14.0	40.0	28.0	160.0
3	36.8	0.0	110.4	0.0
4	5.5	87.8	22.0	702.4
5	183.1	1.0	915.5	10.0
6	5.0	0.0	30.0	0.0
7	10.0	0.0	70.0	0.0
8	0.0	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0
Sub Total	268.9	133.3	1190.4	881.4
Total	402.2		2071.8	

Table 5. First Revision of Travel Chart.

To \ From	In	F	A	B	G	E	C	H	D	Out	
In											0
F	4										4
A	5.5										5.5
B	13		1								14
G	10	4									14
E	40		4.5	13			1				58.5
C	10.8				14	40		1			65.8
H				1		13	64.8				78.5
D						4.5		73.8			78.3
Out						1		4	78.3		83.3
	83.3	4	5.5	14	14	58.5	65.8	78.5	78.3		

Table 6. Calculation of Efficiency for Revised Travel Chart.

Dist. From Diagonal (Units)	Total Volume		Moment	
	Below (Forward)	Above (Backward)	Below (Forward)	Above (Backward)
1	261.9	2	261.9	4
2	49.5	0	99	0
3	26	0	8	0
4	12	0	48	0
5	40	0	200	0
6	10.8	0	64.8	0
7	0	0	0	0
8	0	0	0	0
9	0	0	0	0
Sub Total	400.2	2	681.7	4
Total	402.2		685.7	

Conclusions

(1) Travel charting is a useful technique where process type layouts exist or are contemplated.

(2) The travel chart allows a large quantity of data to be condensed for critical analysis.

(3) The travel chart facilitates measuring plant layout and material handling efficiency quantitatively.

(4) The data used on the travel chart must be selected and treated according to pre-determined assumptions. The results obtained are no better than these assuptions.

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Statistical Analysis Aids Process Control

By Edwin M. Bartee

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In every manufacturing process there exists any number of variables. In most cases the number of operational variables are many but the number of significant variables are few. A common operational approach is to be so appalled at the complexity of the variables that exist, the solution to the problem is regarded as impossible.

The statistical approach is to factually determine what variables are significantly important in the process, and, by a process of elimination, place these variables in control. The degree of control over these variables determines the degree of conformance to operating requirements.

By measuring variations and deviations it is possible to determine the ability of an operation to meet the requirements imposed on it. Such an analysis points the way to sensible modifications of the operation method or may lead to a revision of specifications. These methods of control can quickly establish the level of quality, predict impending trouble, and disclose causes.

Statistical methods of analysis and control have been applied to one of our quality problems to aid supervision increase product recovery and reduce salvaging costs.

Our structural mill was recently confronted with a rather close commercial gauge tolerance on certain sizes of aluminum rod. The recovery realized on these products was too low because the commercial gauge tolerances were not being consistently met. Processing costs, both in rolling and finishing, were too high because of extra operations involving rerolling, sizing, resizing, and salvaging.

The rod is hot rolled from a 6" x 6" aluminum bloom through a series of gothic and round rolls. (Fig. 1). By rotating the blooms 90° between each pass a finished rod is obtained that is practically round. The problem, of course, is to obtain a degree of roundness that will conform to commercial tolerances.

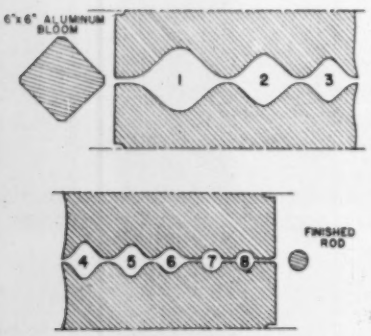

Figure 1. Typical series of gothic and round rolls for processing aluminum rod.

In order to improve the recovery the following problems had to be solved:

1. Since the rod shrinks after hot-rolling it was necessary to determine accurate allowances for this shrinkage before any reliable checking of the gauge could be accomplished during hot rolling.
2. The variables significantly affecting gauge variation had to be determined.
3. These significant variables then had to be placed under control in order to obtain any improvement in gauge variation.

Thermal laws told us that the amount of metal shrinkage is directly proportional to the heat loss. The solution to the problem of predicting this shrinkage involved the determination of the true relationship between these factors for the material being processed.

An initial study was made to measure the gauging temperature and the shrinkage that resulted by cooling to room temperature. Substitution of known values was made in the two equations:

$$e\,Y = N\,a + b\,e\,X$$
$$e\,X\,Y = a\,e\,X + b\,e\,X^2$$

Where:

Y=Shrinkage, inches/inch diameter

X=Gauging temperature, degrees F.

The value for the two constants, a and b, were determined by solving the two equations simultaneously. The relationship between gauging temperature and shrinkage was then expressed as a formula in the form:

$$Y = a + b\,X \quad (1)$$

The gauging temperature (X) that existed after hot-rolling was found to be dependent upon the initial temperature of the bloom before rolling and the time that elapsed while hot-rolling the rod. In order to control shrinkage between required limits it was necessary to determine to what limits these two factors had to be controlled.

This problem was solved by the method of multiple correlation using the three equations:

$$e\,X = N\,a + b\,e\,X_1 + c\,e\,X_2$$
$$E\,X\,X_1 = a\,e\,X_1 + b\,e\,X_1 + c\,e\,X_1X_2$$
$$e\,X\,X_2 = a\,e\,X_2 + b\,e\,X_1X_2 + c\,e\,X_2^2$$

Where:

X =Gauging temperature, degrees F.

X_1=Temperature of bloom before rolling, Degrees F.

X_2=Processing time, minutes.

Values for the constants, a, b, and c were determined by substituting known values in the three equations above and solving simultaneously. The relationship between gauging temperature, bloom temperature, and processing time was then expressed by a formula of the form:

$$X = a + b\,X_1 + c\,X_2 \quad (2)$$

Since equations (1) and (2) have a common term, X, they were made equal to each other, thus eliminating X from the formula. The relationship between shrinkage, bloom temperature, and processing time was then expressed by a formula of the form:

$$Y = a + b\,X_1 + c\,X_2$$

Thus, the amount of shrinkage that could be expected was known and its relationship to the operational factors affecting it was known. In order to control shrinkage it was then only necessary to control the two process variables, bloom temperature and processing time.

Having established an accurate measure of gauge on the mill, it was then necessary to determine what factors affected actual gauge variation. General knowledge of the process pointed up eleven different variables that should be considered as having a possible significant effect on gauge variation. In an initial study the value for each of these variables was recorded along with the resulting rod gauge. By using the statistical technique called analysis of variance, only three of the eleven variables were determined to have a significant effect on gauge variation. Therefore, the problem of controlling gauge variation resolved itself to the control of only three variables in the process: Bloom temperature, cycle time, and skill of the Finish Rod Feeder.

Statistical methods were then employed to assist operating personnel in controlling rod gauge. Operating instructions were issued to familiarize the mill personnel in the new procedures designed to control bloom temperature and cycle time. The skill of the Finish Rod Feeder was found to be a direct function of the variation in the rod gauge. It is this man's responsibility to feed the rod into the last pass properly to obtain maximum roundness. Those feeders that needed the most training were immediately

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Applications of Nomography in Wage Incentives

By Dr. Dale Jones

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Most jobs adapted to wage incentive coverage entail but a limited number of earnings-determinant conditions, warranting use of pre-determined, tabulated wage incentive standards. Each size, type, etc., of product accommodated by such jobs is assigned a separate incentive standard well in advance of production. Some jobs, however, entail a multitude of earnings-determinant conditions, not only due to size and type of product but also due to variation of quality, work load, job method, basic pay rate (in the case of piece work) and other factors. Under such conditions it is often difficult to justify the engineering and clerical effort necessary to calculate, tabulate, apply and modify predetermined incentive standards. Accordingly, the incentive standards for jobs in this category are often left in equation form. Then, individual standards and allowances are calculated directly in accordance with change of earnings-determinant conditions.

Shortcomings of Formulae

The practice of expressing incentive standards and allowances in equation form has proved generally undesirable. In the first place, even the more simple equations and/or routines oftentimes appear complex to foremen, time keepers, rate clerks and others who, for economy reasons, are delegated responsibility for their use. Thus, different persons may come up with different incentive standards allowances for any given set of conditions, causing inequities in payment for work done. Also, certain persons may become lax in applying the seemingly complicated formulae. These tendencies are often realized by operators paid via the formulae, tending to leave impressions of arbitrariness.

With few exceptions, the history of wage incentives reveals that equity at the expense of simplicity is preferable to simplicity at the expense of equity. The equation aims for equity but its mode of expression (its lack of simplicity) tends to defeat its objective when it represents the final expression of incentive standards and allowances. Now, keeping in mind the previously cited unfeasibility of pre-determined, tabulated incentive standards for certain types of work, how can both the equity intended via equations and the simplicity intended via tabulation be achieved? I have found that the alignment chart, also called the nomogram or nomograph usually provides the answer to this question.

The Nomograph

The nomograph, pioneered by Professor M. d'Ocagne, Polytechnic School of Paris in the late eighteenth century is the graphical representation of an equation of three variables. Two or more nomographs may be combined to accommodate more than three variables. Also, nomographs may be used in conjunction with cartesian graphs to further extend graphic calculation.

The principal advantage of the nomograph is its simplicity: the complexity of the calculations it represents is not reflected in its use. Thus, it permits the delegation of calculations to persons of limited or no mathematical knowledge. Also, nomographic calculations are generally more rapid than those made with the slide rule—in addition they may be more accurate, depending on the size and designs of the charts: an overall accuracy tolerance of plus and minus one percent (or less) is quite common. Finally, the nomograph gives virtual complete insurance against omission of steps in calculation, a mistake not uncommon in slide-rule calculations. These advantages tend to explain why more than 1,700 standard nomographs have been developed and published.[1]

The "set-up" or construction time of the nomograph is its only general disadvantage. However, its construction mechanics are simple and easily mastered. With but little experience one can learn to construct the charts with surprising rapidity and accuracy. Because of the general availability of publications[2] on the subject of nomography, instruction in the construction of same is avoided in this discussion. Instead, two special purpose nomographs designed for use in wage incentive administration will be described.

A Simple Nomograph for Evaluating Operator Idleness Allowances

The first nomograph to be described was designed for use in the phenolic molding department of a large plastics molding plant. This department consists of 333 mold presses and an average of 80 operators and 4 foremen per shift for three shifts.

The operators under consideration tend mold press assignments consisting of from two to five presses, depending on the nature of products molded, frequent mold change-over, mold repair and other factors. They are all incentive paid. The incentive standards are based on operator servicing (hand) time only. Separate payment is made for operator idleness inherent in the assignments, which varies significantly from operator to operator and, for given operators from day-to-day and sometimes even from hour-to-hour, depending on number of presses tended and products run on the presses. It is the calculation of these separate idleness payments or allowances that brought about need for the nomograph illustrated in Figure 1.

The necessity of evaluating operator idleness allowances was so frequent as to require one clerk per shift for three shifts. However, since each of the four foremen per shift had but twenty operators in his charge, it appeared, after all relevant factors were considered, that it would be feasible to have foremen rather than clerks evaluate operator idleness and initiate written authority for compensation for same—thereby saving the expense of three clerks. The standard procedure which had been prepared for instructing the foremen how to evaluate the operator idleness allowance for any given work load was as follows (Note: see "Graphical Determination of Work Loads for Multiple Machine Assignments," Journal of Industrial Engineering, May, 1953, for some clarification of the following, which of necessity must be brief):

A. Refer to the assignment card representing the assignment under consideration.
B. Total, on the card, the recorded servicing times (of the productive presses) per battery cycle.
C. Determine the battery cycle time. (3)
D. Subtract B from C.
E. Divide D by C.
F. Multiply E by the number of hours the work load under consideration prevailed, to determine the idleness allowance time, in terms of hours, to be credited to the operator.

The calculations involved in steps D, E and F gave cause for the nomograph shown in Figure 1. Efforts had been made to instruct the foremen in use of the slide rule. Most of them learned enough to make the simple calculations called for in D, E and F. Some, however, did not learn. The resultant inequities and the need for a means of verifying the allowances to the operators made it desirable to make the calculations via the simple nomograph rather than the slide rule.

The standard procedure for evaluating operator idleness allowances through use of the nomographs in Figure 1 is as follows (note the broken lines in Figure 1):

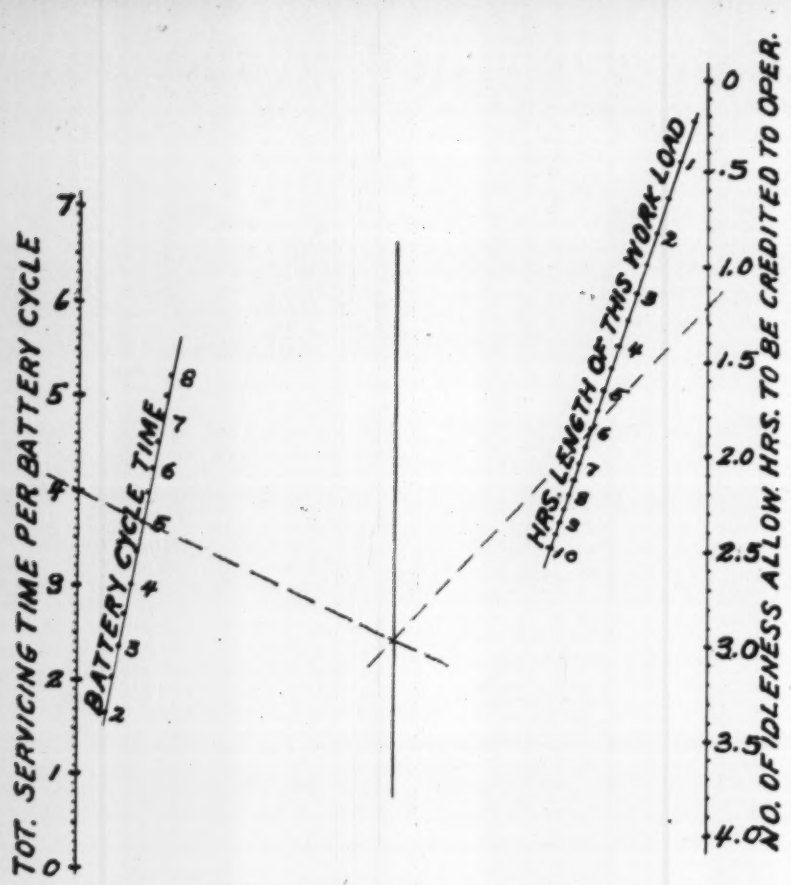

Fig. 1. A simple nomograph used to evaluate incentive-paid operator idleness allowance time in phenolic molding assignments.

A. Refer to the Assignment Card representing the assignment under consideration.
B. Total, on the Card, the recorded servicing times (of the productive presses) per battery cycle.
C. Determine the battery cycle time.
D. Using the nomograph and a straight edge align the B value with the C value on the B and C scales and place the pencil point at the point where the straight edge intersects the center line.
E. Align the straight edge with the pencil point and the point corresponding to the number of hours the work load under consideration prevailed (on the E scale) and note the point of intersection on the right-hand scale, to determine the idleness allowance time, in terms of hours, to be credited to the operator.

Each foreman was provided with a copy of the nomograph in a celluloid envelope and a plastic straightedge. With a little practice, all foremen became proficient in accurately evaluating operator idleness allowance through use of the simple nomograph. The nomograph seemed more acceptable to the operators than the slide rule as a means of evaluating idleness allowance.

Nomographic Determination of Incentive Standards

The nomographs shown in Figure 2 are combined with cartesian curves to accommodate an equation of seven variables. This tool was developed to provide a means of promptly, equitably modifying incentive standards in accordance with change of operator work load.

The department under consideration consists of 120 looms divided into assignments of 4 to 20 looms per weaver, depending mainly on cloth produced: loom servicing requirements (down-time, usually due to warp and fill yarn breaks) varies significantly among cloth types. The weavers experience significant degrees of unavoidable idleness due to (usually economically warranted) work load limitations. This idleness varies in accordance with frequent variation of weaver work load.

The weaver's work load is dependent principally on the extent of servicing demand per loom and the number of looms in the assignment. The extent of servicing demand per loom, dependent principally on yarn breaks, varies significantly for any given cloth, sometimes from day-to-day, due to variation of humidity, yarn quality and other factors beyond the weaver's control. Thus, frequent yarn break-frequency studies are necessary in order to maintain properly weighted loom servicing time per 10,000 picks (the cross threads in a bolt of cloth) required for equitable incentive standards.

After determining the average *expected* servicing time per unit (assuming 80 points or 133 1/3 per cent productive effort of the weaver, and taking personal allowance into consideration) on the basis of a yarn break-frequency studies and elemental expected times, the clerk charged with the duty of administering the incentive standards must, in the absence of Figure 2, performs the following calculations (Note: the accompanying Table I shows the calculations necessary for assignments of 6-10 looms producing a cloth with a .13 work load in absence of machine interference):

1. Establish the operator work load represented by the assignment, in the absence of machine interference (4). This is done 1. by dividing the average expected servicing time per 10,000 picks by the average expected total time, neglecting machine interference, per 10,000 picks (total time, as referred to here, equals external or down time servicing and personal time plus automatic time) and 2. by totaling the individual work loads thus determined for the products in the assignment.
2. Refer to a table (5) and estimate, on the basis of the above determined work load and the number of machines under consideration, P_2, the portion of over-all time the weaver would be unavoidably idle on assumption the above determined work load value actually prevails and the looms are randomly tended.
3. On the basis of 2. above, determine the actual servicing minutes per hour to be expected of the operator: =60 minutes (1—degree idle).
4. In accordance with the mill's policy of granting 100 per cent pay for expected idleness, assuming 133⅓ per cent productive effort on servicing duties, establish the operator's expected over-all earning efficiency for the conditions under consideration:
   $E = P_1E_1 + P_2E_2 + \ldots + P_nE_n$
   where P_1 represents the portion of over-all time the operator spends on Activity 1, P_2 on Activity 2, etc., E represents the operator's expected earning efficiency on Activity 1, E_2 on Activity 2, etc. Under the above mentioned policy this equation becomes:
   $E = 133\frac{1}{3}P_1 + 100P_2$ where P_1 represents the weaver's expected work load, in this case $1 - P_2$, decimally expressed and P_2 represents the previously determined degree of idleness due to work load limitations, decimally expressed, expected of the weaver.
5. Determine the expected production per elapsed hour by dividing the average expected servicing and personal time per unit established in 1. above into the expected actual servicing minutes per hour established in 3. above.
6. Divide the expected production per elapsed hour determined in 5. above by the E value established in 4. above to arrive at the incentive standard expressed in units per hour.

As one takes a set of assumed values and follows the procedure just described and illustrated in Table I, the practical shortcomings of the procedure tend to

TABLE I. Breakdown of calculations necessary for establishing weaving incentive standards when Figure 2 is not used.

No. Machs.	*Wk. Load Per Mach.	Total Wk. Load	P_2 Portion of Oper. Idle Time (Table)	P_1 Portion of Oper. Work Time $(1-P_2)$	E $E_1P_1+E_2P_2$ or $1.33P_2+100P_2$	T Actual Serv. min. per hr. $=60P_1$	H ** Expect. Output (picks) per Hr.	*** Std. Output per Hr $=H\div E$
6	.13	78	.28	.72	1.240	43.2	38,400	31,000
7	.13	91	.18	.82	1.273	49.2	43,730	34,400
8	.13	104	.10	.90	1.303	54.0	48,000	36,920
9	.13	117	.05	.95	1.317	57.0	50,670	38,480
10	.13	130	.00	1.00	1.333	60.0	53,330	40,000

* Actually, Work Load per machine will usually differ for different numbers of machines in assignments because of difference of walking time.

** =T÷Expected servicing and personal time per 10,000 picks.

*** When the operator is paid on the basis of production count only, as assumed in this article, E= actual output per hour÷Standard output per hour. Therefore, Standard output per hour=Expected output per hour÷E.

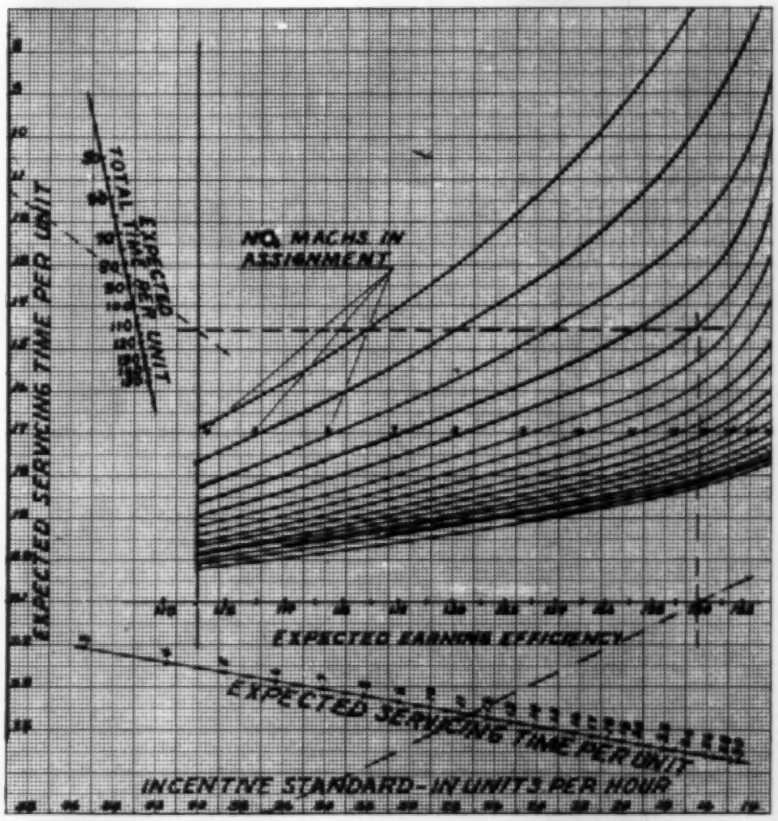
EXPECTED SERVICING TIME PER UNIT
TOTAL EXPECTED SERVICING TIME PER UNIT
NO. MACHS IN ASSIGNMENT
EXPECTED EARNING EFFICIENCY
EXPECTED SERVICING TIME PER UNIT
INCENTIVE STANDARD-IN UNITS PER HOUR

Fig. 2. Nomographs integrated with cartesian curves—used for establishing incentive standards in certain weaving assignments.

become apparent. First, the procedure is quite complex to the low-paid rate clerk: It is not only vulnerable to mistakes in incentive standards due to error in calculation but also due to omission of steps and mis-placement of decimal points. When properly employed, however, the procedure does produce equitable incentive standards. Accordingly, the tool shown in Figure 2 was developed in order to effectuate the desired equity by insuring against error. Of course the desire for rapidity and simplicity of calculations also contributed toward the development of the tool.

The procedure necessary for using Figure 2 in behalf of any given weaving assignment in the department under consideration is as follows (note broken lines in Figure 2):

1. On the basis of yarn-break frequency studies and standard elemental times, establish the average expected servicing time per loom in the assignment under consideration, using a straight edge, align this point with the average expected total time per unit.
2. About the point where the straight edge intersects the ordinate of the family of curves, revolve same to a horizontal position.
3. About the point where the now horizontal straight edge intersects the curve for the number of machines in the assignment under consideration, revolve same 90 degrees to a vertical position.
4. About the point where the now vertical straight edge intersects the abscissa of the family of curves revolve the straight edge to align the average expected servicing time per loom.
5. Note, at the point where the straight edge intersects the lowest horizontal scale, the incentive standard, in thousands of picks per hour for the conditions under consideration. As work loads change significantly due to change of yarn break frequencies, change of products or number of machines in the assignment, the foregoing procedure is repeated and new standards established. Note that one can quickly determine, through use of Figure 2, if a given change is significant, i.e., enough to warrant a change in the incentive standard.

Discussion

Two typical, special applications of the simple Z type of nomograph have been presented in this article. It is possible to solve most equations entailed in industrial engineering via nomographs. Whether nomographic solution is economic in any given situation is dependent on the number of calculations entailed and the engineer's knowledge of nomographic construction: when one is experienced in nomography, this number need not generally be large.

In considering the feasibility of designing nomographs in specific cases, it will be well for the engineer to consider the following advantages of same in comparison with other methods of calculation:

1. The number of calculations required to solve an equation are generally reduced.
2. The calculations are simpler, requiring the alignment of but two values at a time in an illustrated sequence. This makes possible the delegation of calculations to persons not schooled in the slide-rule.
3. The calculations can be made more rapidly.
4. The calculations can be made more accurately, provided the scales are properly designed.
5. Those who are affected by the calculations (workers in this case) may more easily verify the accuracy of same.

To date, nomographs have been used to a very limited extent in industrial engineering. Most applications involve standard nomographs used to calculate cutting times for machine tools, in setting time standards. There are apparently numerous opportunities for the extension of nomography and its many advantages in industrial engineering endeavor. The nomographs required, however, are of the special purpose rather than general purpose type. Accordingly, the speed with which nomography takes its place in industrial engineering will be dependent principally on the speed with which industrial engineers close to problems warranting nomography will learn this simple art.

(Continued on Page 26)

PRESIDENT'S MESSAGE

(Continued from Page 2)

existence. From such a fortunate "biological accident" in the then current organizational practice evolved the present-day management philosophy which realizes that the basic objectives of any economic organization should be stated in terms of human values.

The impact of the arguments of labor relations and organization people over the last 15 years is evidenced by the number of organization manuals and other written policy statements of the overall objectives of the enterprise. The thinking back of this activity seems to be the recognition that the *first* requirement in developing adequate, consistent policies and practices throughout the organization is the postulation of the over-all objectives of the enterprise. It is also important to note that in order to have the resulting practices acceptable to the human beings making up the company, the over-all objectives must be consistent with our American concept of individual freedom and growth. I am certain you will agree that the result has been a broadening of the objectives and enlargement of the values involved in management planning.

After reading over several such statements of company objectives and Ernest Dale's fine book "Planning and Developing the Company Organization Structure," a president of a small company remarked to me that in his opinion an appropriate statement of the objectives for all human organizations could be made in the following capsule form:

> "To so construct and operate the organization as to make the largest possible contribution to the growth and advancement of the maximum number of individuals."

Space does not permit the discussion which should be made of the many implications in this statement. This is certainly a fine objective to have, one that requires a patient, self-conscious, self-restrained management to implement. Perhaps it should be pointed out that such objectives are not incompatible with operating at a financial profit. In fact, when kept in mind realistically and continuously, profits will tend to be maximized in the long run. Perhaps this portends future developments in the labor relations approach.

What is the effect of all this upon industrial engineers?

If we agree that there has been an observed determination on the part of many of our companies to more adequately and completely align their objectives with the human values of our society, then the effect will be to re-examine the assumptions and bases involved in the design of the several industrial engineering systems in a company. Among the questions which should be asked are:

> "Do our present systems provide results in line with our objectives?"
>
> "Do our present 'Effectiveness' figures or cost-reduction analyses really include *all* the costs involved?" or
>
> "Are all the values implicit in the objectives considered in the design and evaluation of a given system?"

In my opinion the professional industrial engineer will be called upon to answer these questions. This will be a real challenge to broaden the basis of analysis, to develop a methodology which permits all the factors of cost and value to be considered. There should be no room for complacency when considering the challenge of future industrial engineering design problems. The need for close cooperation and mutual development with the social sciences as well as the appropriate mathematical areas should be evident.

JOB DESIGN

(Continued from Page 6)

problem, and a brief review of primary approaches to job design and their limitations. The job-centered approach is suggested as a basis for the development of a job design theory and research thereon, and the economic productivity criterion (minimizing total cost) is advanced as a way to evaluate various possible designs.

While the research needs posed by an attempt to formulate a job design theory are very difficult to investigate, some questions immediately arise: What are the present methods used by American industry in designing jobs? Is the problem of job design seen as a realistic one? How are various job designs evaluated in American industry? What are the principles and precepts used by persons who design jobs? In a later paper we will report the results of a survey which was directed toward obtaining answers to these and other related questions.

MACHINE REPLACEMENT

(Continued from Page 12)

What is the fallacy in each of the first three approaches?

The fallacy in the first approach is that it fails to recognize the fact that past events are irrelevant in an economy study except insofar as they aid in the prediction of future events.

That past expenses are irrelevant in our particular problem can be verified by an examination of the comparison of the total expenses for the entire seven year period of both alternatives. Any expenses that occurred before the time of decision are common to both alternatives, and will not, therefore, affect the difference between these alternatives. For example, suppose the original softeners have been *given* to the manufacturer. In this case the total expenses for both alternatives would be reduced by $7,000, but the diference between them would remain $600 in favor of installing the new equipment.

What past events were used in approach number one? The book value represents a combination of two past events —the actual cost of the original equipment and the life that was originally estimated for it. The book value represents that part of the expense that has not yet been written off in the books of account. The total original expense, however, was actually incurred—and nothing

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that is done one year later can change that fact.

The error in approach number two is perhaps more obvious. Any time an arbitrary pay-off period, such as four years, is selected, such period can actually be identical with the economic life of the asset only by great good fortune. In our particular example, it is perhaps obvious that that pay-off period should have been six years—but a rigid company policy of a four-year pay-off period would, as we have seen, yield an incorrect decision.

The short pay-off period requirement is frequently defined as "conservative." It is difficult, however, to support as conservative a method that can be right only by chance, and which costs the company hard cash when wrong. It is just as expensive to fail to purchase a machine that would save money as it is to purchase one that will lose money.

Further, as Terborgh points out in *Dynamic Equipment Policy*, if a short pay-off period is conservative, presumably a shorter pay-off period would be even more so. Why, then, stop at a four year period? Why not a one year-or a one month—period?

In brief, there seems to be little to recommend the short pay-off period except custom.

But what of the third approach — that of using the MAPI formula? Is this not valid? It has certainly received wide publicity, and is being used increasingly by progressive companies. No attacks on it on theoretical grounds have appeared in the technical press. And yet it certainly signals the wrong action in our problem. Why?

In any formula developed to aid in the solution of a problem as complex as that of machine replacement, certain simplifying assumptions are necessary—and the formula developed is valid only when these assumptions fit the actual case in point. The MAPI formula is no exception to this general statement. In developing it, Terborgh assumed, among other things, that history would repeat itself — that is, that an endless succession of machines would be required, each of which had the same first cost.

In our problem, this assumption is clearly violated; we require the service for only six more years, we therefore cannot legitimately use the MAPI formula in its solution.

In general, we should not use any formula until we assure ourselves that our particular problem satisfied the assumptions made in developing the formula.

What, then, of approach number four? Can we conclude that it is of sufficient validity to be used in all situations? No, we cannot. We can only conclude that it yields the correct answer to the particular problem we have examined. In this problem many simplifying assumptions were made. For example, it was assumed that interest charges could be neglected. Practically, interest charges are never zero. Even if ownership funds are used to purchase a piece of equipment, an interest charge should be made since such funds would earn a return if utilized elsewhere.

Table 4

Source of Expense		Cost per Year If: Old Asset Is Kept	New Asset is Purchased
Capital Recovery	Depreciation	$\frac{\$1{,}800}{6} = \$300.00$	$\frac{\$4{,}200}{6} = \$700.00$
	Average Interest	$\frac{\$1{,}800+300}{2} \times .05 = 52.50$	$\frac{\$4.200+700}{2} \times .05 = \$122.50$
Operating Costs		$900.00	$400.00
TOTAL ANNUAL COST		$1,252.50	$1,222.50

The inclusion of the factor of interest is not difficult in this approach—but the indication of the legitimacy of the method using an example similar to the one considered in this article requires extensive use of compound interest theory. By the use of the theory, however, it is possible to show that the method does give the correct answer.

This approach could be extended to include the requirement that a return be made on an investment. To illustrate, let us change the statement of the problem to include the fact that the new equipment would not be installed unless it would pay a return of five percent.

In order to obtain an exact solution to this new problem, we would resort to the use of interest tables yielding an exact annual amount for capital recovery. An excellent approximation to the exact cost of capital recovery, however, is given by the sum of the depreciation per year and an average interest charge. (The legitimacy of this approximation is not affected by the manner in which depreciation is handled in the company's books of account, not by the manner in which the value of the asset actually decreases with time.)

The validity of this approximation can be demonstrated mathematically. Perhaps its reasonableness can be demonstrated logically.

In the first year, interest should be chargeable to the entire investment but in subsequent years to the investment less accrued reserve for depreciation. This is explainable by the fact that the reserve for depreciation can be used to pay off the principal of the loan (if any) over the life of the machine—or if this amount is put back into working capital, it can be used for other gainful purposes.

In general, the average interest charge can be shown to be the average of the first and last interest payments. The first interest payment is on the entire investment; the last is on the amount by which the investment is depreciated each year plus the interest on the salvage value, if any.

Assuming a five percent interest charge, the annual cost comparison using Grant's approach therefore becomes that shown in Table 4.

Conclusion

If interest is worth five percent, it will be more economical to install the new machine.

It is thus obvious that the interest rate can be an important factor in a machine replacement decision. The choice of an appropriate interest rate is not an easy one, but a guide to the proper choice can be found in Grant's or Terborgh's texts.

What can we conclude from the analyses we have made? First that there are basic fallacies in several widely used approaches to machine replacement decisions — and that these fallacies can be conclusively demonstrated by using a simple example. Second, that machine replacement theory is not a simple theory. It can be simplified in certain cases — but such simplification should be used only when the assumptions on which they are based are known and are appropriate to the actual problem at hand.

While it is not possible to become a skilled replacement analyst in one easy lesson, the tremendous losses that can be prevented by proper machine replacement analysis indicate the need of properly trained men. These losses are particularly important because they are generally not apparent — no accounting system has yet been devised that will reveal the loss incurred by not making an economical machine replacement.

The stakes are large — the time has long since past when we can look with complacency on dubious methods of making machine replacement decisions.

STATISTICAL ANALYSIS

(Continued from Page 16)

determined by comparing the range charts for each man. (Fig. 2)

A control chart was used to obtain improvement in gauge performance. The results obtained from the use of this chart immediately indicated the need for follow-up, from time to time, on the three significant variables in the process. It also gave a more positive basis for adjusting screw pressure on the mill to obtain the proper gauge level.

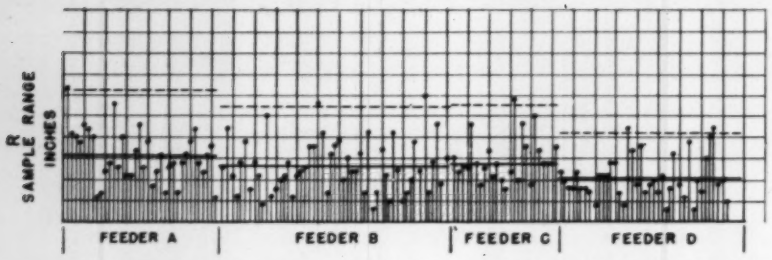

Figure 2. Range chart for individual finish feeders. The range serves as a relative measure of feeder skill.

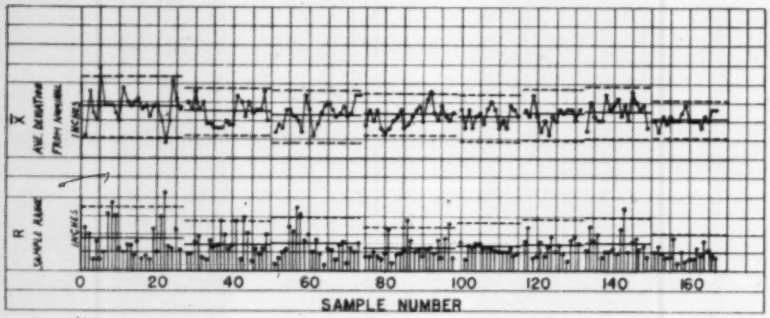

Figure 3. Guage control chart, 26" structural mill.

The procedure in using the control chart is as follows:

1. The foreman takes a sample of the rod gauge, consisting of six readings.
2. The sample values for X (average) and R (range) are than computed and plotted immediately on a control chart.
3. The results of the sample are then called up to the mill when adjustments are necessary, as indicated by the control chart.
4. The head roller makes the needed adjustments, the rolling is continued, and further samples are taken.

The control chart in Fig. 3 shows the progress that has been made on this problem. Over a period of only a few months, we have established gauge control on this mill and our rod recovery has doubled. It is an example of supervision supplementing their knowledge of the process with objective methods of statistical control. Trouble-shooting has been resolved to follow-up on those significant variables in the process as determined by equally objective methods. Maximum quality has been realized with maximum efficiency and economy.

OFFICE IMPROVEMENT

(Continued from Page 10)

in organization analysis, this is one area which should receive more of his attention.

Individual job descriptions of each of the office jobs will help to disclose the exact nature of the duties of each employee. It should help disclose duplication of effort and the spreading of some person's efforts too thin. As an example of the value of job analysis, Whitmore[5] cites the following case, "Job analysis in one company revealed that in one office 5 executives maintained complete duplicate files in their own departments of all correspondence, all records, and all statistical reports. This, despite the fact that an excellent central filing department was available to serve them. These extra files, some of which had not been cleaned out and dead papers destroyed or transferred in more than 10 years, took up space, required extra time to maintain, and cost money to operate. They had been installed years ago. Then the company revamped its central files. At one time, when central files were inefficient, there seemed to be adequate reasons for these five executives to maintain private files. Those reasons disappeared more than 10 years ago."

It is very helpful to get a rough measure of work distribution in order to determine the duties that are consuming most of the office employee's time. This work distribution analysis should help answer the questions: (1) Is the maximum time being spent on the major activity? (2) Are the workers' skills being used most advantageously? (3) Are the employees specialized in their respective positions? and (4) Is the work load balanced? One of the common ways of securing the work distribution data is to have the employees keep a log of their duties and the amount of time consumed in doing each task. A more recent development that offers great possibilities in collecting information of this type is the work sampling or ratio-delay technique. Carrier Corporation, Syracuse, New York, adapted ratio-delay to the analysis of clerical work and found it very effective. Likewise, a technique for taking random motion pictures, which was developed in the Purdue University Motion and Time Study Laboratory by A. N. Paul and L. Hayet, shows real promise in securing data of this type. This device was used to analyze the activities of a stenographer over a two week period and proved to be a convenient and accurate method of determining the activities and percent of time spent on each of these activities.

The "reports and forms" analysis should be conducted to determine if any reports or copies of reports can be eliminated and if the best forms are being used. This analysis should help answer the questions: (1) Can letters and reports be eliminated or simplified? (2) Can a form be eliminated? (3) Has writing or typing been reduced to a minimum on the form? (4) Has the spacing on the form been designed to facilitate the use of a typewriter and for a minimum of tabulation? (5) Have forms been combined such that one writing will produce copies for several functions, for example, the writing of a purchase order which at the same time produces a receiving report, material control copy and accounts payable control. The potential savings from reports and forms analysis is tremendous, as is attested by the following examples:

(1) In one company, 23 forms were reduced to 7. In transportation billing, there was a reduction of 40% and the amount of paper used was reduced by more than 50%.

(2) "Redesigning forms used in the hourly personnel records department of Ford Motor Company made it possible to concentrate all the necessary records on three forms and a jacket. These 3 forms replace 13 which were formerly used to provide the same information."[6]

(3) "Redesigning of forms and use of an electric typewriter in place of a manual machine enabled a famous glass manufacturer to increase production of master route sheets from 40 sets per day to 160 sets per day."[7]

(4) "A check in one department that prepared 15 monthly reports, with a total of 134 copies, resulted in the following:

1. One complete report was eliminated.
2. Thirty-eight copies, or 28 percent of the total, were eliminated.

[5] Eugene Whitmore, "Why Incur the Expense of a Job Inventory," American Business, February 1953.

[6] American Business, February 1953, op cit.

[7] American Business, op cit.

3. Ten copies were being sent to the wrong individuals and had to be forwarded each month."[8]

In considering the content of the work simplification phase of the total methods improvement program, the work simplification approach which has proven so successful in improving manufacturing methods, should prove equally valuable in improving office methods. The steps commonly contained in this approach include:

Selecting a job for improvement.
Analyzing the job to get all facts pertaining to it.
Questioning each detail of the job.
Developing an improved method.
Applying the proposed method.

In selecting office jobs for improvement, stress should be placed on those which the Work Distribution Analysis has disclosed to be most time consuming. Inasmuch as approximately 85% of all office costs result from labor costs, the primary aim should be to reduce the labor requirements of each task.

In analyzing office jobs excellent use can be made of the many analysis techniques with which Industrial Engineers are familiar. The flow of paper work can be charted by means of a Flow Process Chart and Flow Diagrams. In those cases where the interrelationship between the flow of papers and employees becomes very complex, special flow process charts of the type developed by IBM, Standard Register Company or Mundel[9] will prove very useful.

With the increased use of computers and other machines in the office, the Man and Machine Chart should prove of increasing value in attaining the maximum utilization of machines. In those operations involving no machines, the Right and Left Hand Operation Chart will prove to be a useful tool. In every situation we should attempt to use that analysis technique which will provide the best information about the present way of doing the job. Oftentimes, this might best be accomplished through the use of motion pictures. Memomotion[10] offers an excellent way of recording the simultaneous actions of a number of workers, and it should not be overlooked as a convenient way of collecting data on office operations.

In questioning each of the steps of the present method of performing the task, consideration should be given to the application of the maximum number of the principles of motion economy. The principles which are most commonly violated and should not be overlooked in the office work simplification program include:

1. *The use of the normal work area* —in most offices, the use of standard desks, typing tables, filing cabinets, and other equipment shows clearcut failure to adhere to this principle.
2. *Prepositioning of tools and materials*—as in item 1, the use of standard equipment has led to violation of this principle.
3. *The height of the workplace should be correct*—too often, the use of standard equipment results in the violation of this principle.
4. *Provision of good conditions for posture.*
5. *Provision of good lighting.*
6. *Two or more tools should be combined in one wherever possible.*

Following the development and application of the proposed method, consideration should be given to the installation of work measurement. Analysis of many clerks, stenographers and other office workers by one management consulting firm has disclosed most of them to be working at about 60 to 70 percent of task. Through the application of predetermined time standards in a number of offices, this firm has been able to materially reduce the number of employees required. Thus, the potential savings possible through the combination of a methods improvement and work measurement program are enormous.

In these days of ever increasing competition management must give attention

(Continued on Pgae 26)

[8] Herrmann, op cit.

[9] M. E. Mundel, "Motion and Time Study Principles and Practice," Prentice-Hall, Inc., New York, 1950.

[10] Memotion involves the taking of motion pictures at a slow rate, such as one frame per second. See Mundel, M. E., op cit.

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Industrial Engineering & Business Administration

By J. V. McKenna

Associate Professor of Industrial Engineering, Syracuse University

It is not necessary to review the entire history of the management movement or of scientific management in America to bring into focus the modern concepts of Industrial Engineering and Business Administration. It is sufficient to observe that previous to 1880, or thereabouts, there was no science of management. Science was considered academic and therefore out of place in practical business affairs. Industrial Engineering was concerned with mechanical problems related to the design of structures and their integration into economical manufacturing units. The human element was generally ignored. Business Administration as an organized field of study did not exist.

Two efforts directed towards the systematization of management, the management movement and scientific management, developed in the years 1880 to 1911. Of the two, scientific management was the more successful in that it achieved an integrated system of philosophy, principles, and techniques. It became the basic rationale of the management movement and the dominant force in applying the scientific method to industrial activities.

Scientific management was the work of Frederick W. Taylor. Its philosophy, principles, and most of its techniques were developed by him as the result of his experiences in solving practical management problems. Scientific management was based on the philosophy that "rule of law" was applicable to all managerial problems and should be made to replace "rule of thumb." All managerial decisions were to be in accordance with the natural laws governing the situation, whether physical, psychological, social, or any other. Taylor believed that the laws appropriate to any situation could be discovered by experiment and systematic study. As a means of discovering these laws, he devised the special techniques of scientific management. They were not methods for managing a given situation but simply tools for analyzing the situation in order to discover the causal factors and their interrelationships. The principles of scientific management were simple statements of apparent truths relative to management in general. An example which comes to mind immediately is the "principle of exceptions."

Taylor's development of the line and staff of organization is pertinent to our discussion. Line and staff organization accomplishes the separation of planning from operating by applying vertically the principle of functional foremanship. At the same time it permits the foreman to maintain one-man control over his workmen and thus overcomes the most serious disadvantage of functional foremanship.

The line and staff organization is one in which a staff is grafted onto a line organization so that the duties of management may be shared by the two. The line organization is charged with operational performance. Officers of the line have responsibility and authority commensurate with it. The staff exists to support the activities of the line. Its special purpose is design; design of an organization and of systems and procedures which will systematize planning and controlling. This is a long-term project which can neer be finally resolved, for conditions change and the design for operation must be changed accordingly. If the staff is to do a good job of design, it must not be directly concerned with the expediencies of day-to-day operation. Line and staff organization provides for the staff the kind of detachment from operating activities which is essential to its success as a design agency. By the nature of their functions both Industrial Engineering and Business Administration are staff.

Industrial Engineering emerged from the period referred to above as an entirely new concept. Scientific management had underscored the improtance of good design in a managerial sense; "a good organization with a poor plant will give better results than the best plant with poor organization."[1] It had demonstrated further that human endeavor, especially when closely related to mechanical processes, could be made vastly more efficient through the use of engineering analysis and synthesis. The province of the Industrial Engineer was therefore expanded to include integration of the human element into the functioning enterprise.

In so extending himself, however, the engineer was conservative. He tended to concentrate his efforts on problems associated with machine and processes because they seemed to him most demanding of engineering knowledge. Whenever the human element was involved in these problems, he applied himself to integrating it into the functioning unit. He did not, however, extend his interests to areas where the human element was unrelated to machines and processes. Industrial Engineering thus came to be recognized as a staff organization at the management level, oriented toward problems which were predominantly of a technological nature.

In order to establish the nature of Industrial Engineering and Business Administration in another area, it is necessary now to move ahead historically to Oliver Sheldon's *Philosophy of Management*, published in 1923. In his book Sheldon defined administration and management:

> Administration is the function in industry concerned in the determination of corporate policy, the coordination of finance, production and distribution, the settlement of the compass of the organization and the ultimate control of the executive.
>
> Management proper is the function in industry concerned in the execution of policy, within the limits set up by the administration and the employment of the organiation for the particular objects set before it.

Business Administration, by its title, lays claim to administrative status. This claim is, at best, only partially valid.

Administration, by its very nature, cannot be scientific. Science deals with objective fact. But business problems are never classified as administrative unless the facts about them are unknown or know only partially. These problems are resolved by the consideration of facts to the extent that facts are available and then by discussion resulting in agreement or by voting. It produces a basis for action rather than the solution to a problem. This process has merit more because the decision achieves general acceptance than because it is the correct decision. There is no infallibility accorded group thinking that does not pertain to individual thinking. If the decision arrived at could be weighed objectively with other alternatives, it might well prove to be the least desirable one. The techniques taught in business colleges are of little consequence at the administrative level, where the important variables do not lend themselves to scientific analysis.

At the administrative level, there is no conflict between Industrial Engineering and Business Administration. Industrial Engineering is not concerned with the resolution of situations by group discussion.

Business Administration is most successful when it operates at the managerial level. Personnel selection and placement, job evaluation, merit rating, psychological testing, employee training, accounting, auditing, budgetary control, etc., are all more closely associated with the execution of policy than with policy determination. At the management level, Business Administration has developed as the instrument for the systematic analysis of business problems unrelated to technological factors.

In the management area, Business Administration is a staff function like Industrial Engineering and possesses equal possibilities for the use of the scientific method. It deals with problems in a different area, problems related to finance,

[1] Frederick W. Taylor, "Shop Management," Trans. of A.S.M.E., 1903 reprinted in **Scientific Management**, New York, Harper & Bros., 1948, p. 62.

distribution, and the human element unrelated to machanical facilities. The applicable sciences are not the physical sciences which are predominant in Industrial Engineering, but rather the social or life sciences. Business Administration is not scientific because these basic sciences have not been fully developed.

Competition between Business Administration and Industrial Engineering at the managerial level is to be expected and should not be regarded as undesirable, for the boundaries between them can be drawn only in this way. A continual shifting of values from time to time and overlapping in some areas combined with the total neglect of others is to be expected. The relationship between them will gradually stabilize as one group or the other demonstrates its superiority in the various fields where the issue is as yet undecided.

The purpose of management is the execution of policy. It is accomplished by good design and efficient operation. An organizational structure must be designed to delineate areas of responsibility and establish lines of authority and communication. Plans must be made for separating the exceptional from the routine and systems designed for handling routine problems in a routine way. Control systems must be designed and standards of performance established. But good design is not all that is necessary for the achievement of corporate objectives. Operation must be efficient and according to plan.

The designer of managerial systems is not necessarily the best operating manager any more than the designer of a typewriter is necessarily the best typist. Ability to design does not imply ability to operate nor does ability to operate imply ability to design. Design should be the responsibility of design specialists and operation the responsibility of operating specialists: the two are quite different personalities.

Neither Business Administration nor Industrial Engineering should be considered complete educational programs in administration or management. At the administrative level, Business Administration teaches the principles of policy making and provides practice in conference techniques under simulated conditions.

There is little doubt that the greatest academic contribution of the College of Business Administration has been the development of an unique method for teaching the techniques of administrative decision-making. The case method requires students to make decisions with respect to typical administrative problems by group discussion. It is the academic equivalent of the industrial conference. In both cases a group is used because it brings to bear upon the problem a variety of approaches arising from different interests, education, and experience.

By practice in the case method students who have the capacity and receive proper coaching develop a logical method of attacking administrative problems and a kind of intuition which enables them to guess the risk involved when they decide upon a course of action not fully supported by facts. The less capable student gains practice in conference participation and some valuable lessons in group dynamics. There is, however, little evidence that this practice does more than develop potentialities that already existed or that it develops them better than the less expensive method of practice on the job.

There is, in addition, a hidden danger in using the case method in undergraduate work. Cases can be assigned only on the assumption that the students are masters of the analytical techniques required for the analysis of such factual data as they are given. There is no possibility of gain from the assignment of a case as part of a first course in any subject. The case method is most successful as an integrating device at the end of the undegraduate curriculum or in graduate work.

Both Business Administration and Industrial Engineering are training for design specialities at the managerial level. Business Administration teaches budgeting, the analysis of market conditions, the design of merit rating and accounting systems, etc. Industrial Engineering teaches the design of manufacturing processes, the layout of plants, the design of cost, production and quality control systems. There is little in either course to prepare the student for management on the operational side.

Success is administration or the operating phase of management is most likely to be achivede by persons who possess a broad general education rather than an intensive one in any special field such as finance, sales, production, or accounting The situation is one which requires generalists rather than specialists. Instruction in fundamental principles is more important than techniques. The objective should be to develop in the individual the ability to analyze, compare, reason, and decide upon a logical basis.

No educational institution in this country seems to have found an ideal means to accomplish these objectives. Because of this, operating managers are currently chosen on the basis of their early performance in some more specialized activity. The graduates of Industrial Engineering and Business Adminstration are strong contenders for managerial positions[2] despite the fact that the two curricula are designed to produce specialists rather than generalists. The time has come when both schools should give up any pretense of educating managers and devote themselves wholeheartedly to the intensive cultivation of their own specialities. It is entirely possible that managers can be developed only by industrial experience, but if it is possible to educate them in colleges, the process will require not only new curricula but also new methods of teaching and evaluating.

2. "The Nine Hundred," Fortune, Nov. 1954, P. 182.

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(Continued from Page 19)

Table 7. TRAVEL CHART
Of Composite Study—Jump Coil, Stator Wind, and Induction Anneal & Shaft Press Fixture
By W. P. Smith Date 6-20-53

FROM / TO	Raw Matl.	LA, W & S	M,SH,SL,	W/B	S/M,W,BLK/	BR/M,V/M	H/T,V/B	G	H/B/M,PL,	W/B,ASS'Y			TOTAL
Raw Mat'l.													
LA, W & S	237		1	14	1	2		1					256
M,SH,SL, 12-2	121	48		9	12	12		8	1				211
W/B	90	7	27		11	10	15		2				162
S/M,W,BLK/S	34	2	3	129									168
BR/M,V/M,J/B	15	57	17	10	32		3	24	1				159
H/T,V/B	6	18	1		23	5				56			109
G	11	5	13		16		36			22			103
H/B/M,PL,D/P	2	1	2		2		12	4		5			28
W/B,ASS'Y	54	118	147		71	131	43	66	24				653
TOTAL	570	256	211	162	168	159	109	103	28	83			

SUMMARY	1	2	3	4	5	6	7	8	9	10	11	TOTAL
FORWARD	542	484	504	900	585	78	1113	960	486	-	-	5652
REVERSE	29	164	255	8	50	12	-	-	-	-	-	518 x 2

SCORE = 6686

OFFICE IMPROVEMENT

(Continued from Page 23)

to all ways in which economies may be realized and the office offers fertile ground for cost reduction. It behooves the Industrial Engineers, then, to take the leadership in promoting and assisting in the establishment of a strong office methods improvement program.

NOMOGRAPHY

(Continued from Page 15)

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2. A recommended publication:
   Rule, John T. and Watts, Earle F., **Engineering Graphics**, McGraw-Hill Book Company, Inc., New York, 1951. Also recommended for brief treatmen of nomograph construction:
   Alford, L. P. and Bangs, M. E., **Production Handbook**, The Ronald Press, New York (see, "Alignment Charts" and "Nomograph Calculations" in index).
3. The battery cycle time of a multiple machine assignment is the time required for the operator to perform a repeating series of events. It is equal to either the total of the operator's servicing time per battery cycle (in which case the operator is completely occupied) or the longest of the machine cycle times* per battery cycle, whichever is the greater. *If some machines experience more than one cycle per battery cycle, consider the total of such times per battery cycle.
4. Machine interference is the idleness a machine experiences when it is non-productive, waiting to be serviced by its operator who is servicing some other machine in the assignment.
5. Jones, Dale, "Graphical Determination of Work Loads for Multiple Machine Assignments," Journal of Industrial Engineering, May, 1953.

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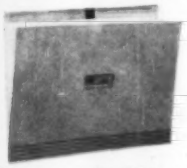

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